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FOURTH SERIES.

VOL. I—[WHOLE NUMBER, CLI.]

No. 5.—MAY, 1896.

PLATE IX.

NEW HAVEN, CONNECTICUT.

1896.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 125 TEMPLE STREET

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXVIII.—*Carbon and Oxygen in the Sun;* by John Trowbridge.

In 1887 Professor Hutchins of Bowdoin College and myself brought forth evidence to show that the peculiar bands of the voltaic-arc spectrum of carbon can be detected in the sun's spectrum. They are, however, almost obliterated by the overlying absorption lines of other metals, especially by the lines due to iron. In order to form an idea of the amount of iron in the atmosphere of the sun which would be necessary to obliterate the banded spectra of carbon, I have compared the spectrum of carbon with that of carbon dust and a definite proportion of iron distributed uniformly through it. The carbon dust and iron reduced by hydrogen was formed into pencils suitable for forming the voltaic arc.* Chemical analysis showed that the iron was uniformly mixed with the carbon dust. Specimens, taken from different sections of the carbons which I burned in the arc, gave twenty-eight per cent of iron and seventy-two per cent of carbon.

The method of experimenting was as follows: That portion of the spectrum of the sun which contains traces of the peculiar carbon band lying at wave length 3883·7 and which has been almost obliterated by the accompanying lines of absorption of other metals, among them those of iron, was photographed. The pure carbon banded spectrum was photographed on the same plate immediately below the solar spectrum, and the spectrum of the mixture of iron and carbon immediately below this. The sun's spectrum can be regarded as a com-

*I am indebted to Mr. John Lee of the American Bell Telephone Co. for his skill in making the carbons and for analyses of the composite carbons.

posite photograph, and the iron and carbon can also be regarded as a composite photograph. It was speedily seen that from twenty-eight to thirty per cent of iron in combination with seventy-two to seventy per cent of carbon almost completely obliterated the peculiar banded spectrum of carbon. This proportion therefore of iron in the atmosphere of the sun, were there no other vapors of metals present, would be sufficient to prevent our seeing the full spectrum of carbon.

The iron in the carbon terminals which I employed greatly increased the conductivity, as will be seen from Table I, which was obtained in the following manner.

The carbons were separated by means of a micrometer screw and the current and difference of potential were measured with different lengths of arc. Table I gives the results for pure carbon. Table II for twenty-eight per cent of iron and seventy-two per cent of carbon.

TABLE I.

Length of arc in mm.	Amperes.	Volts.
1	27	25
2	23	24
3	22·5	20
4	20	18
5	16·5	15

TABLE II.

Length of arc in mm.	Amperes.	Volts.
1	30·5	30
2	29	30
3	27·5	28
4	24	25
5	22	20
6	20	20
7	18	19
8	16	18

The length of the arc could be nearly doubled with the same current and the same voltage by the admixture of 28 per cent of iron. The light was apparently greatly increased, but the difference in color between the pure carbon light and the iron carbon light made measurements unreliable.

Moissan* has shown that the carbon in an electric oven through which powerful electric currents have flowed is free from foreign admixtures. Deslandres has confirmed this and finds only a trace of calcium present. The purification comes from a species of distillation of the volatile impurities. The purest carbon is found at the negative pole. The light of the

* Comptes Rendus, cxx, pp. 1259–1260, 1895.

electric furnace is due to the combustion of carbon. Can we conclude that the sun is also a vast electric furnace?

If the voltaic arc is formed under water its brilliancy diminishes greatly. On the other hand, an atmosphere of oxygen greatly augments its vividness. The question, therefore, whether oxygen exists in the sun is closely related to questions in regard to the presence of carbon, when we consider the temperature and light of the sun.

If suppositions also are made in regard to the magnetic condition of the atmosphere of the sun, it is of great interest to determine whether oxygen exists there, for oxygen has been shown by Faraday, and later by Professor Dewar, to be strongly magnetic.

Professor Henry Draper brought forward evidence to prove the existence of bright oxygen lines in the solar spectrum. Professor Hutchins of Bowdoin College and myself examined this evidence and, after a long study of the oxygen spectrum in comparison with the solar spectrum, came to the conclusion that the bright lines of oxygen could not be distinguished in the solar spectrum. We published our paper in 1885. I have lately studied the subject from another standpoint, having carefully examined the regions in the solar spectrum where the bright lines of oxygen should occur if they manifest themselves, in order to see if any of the fine absorption lines of iron in the spectrum of iron were absent, for it is reasonable to suppose that the bright nebulous lines of oxygen would obliterate the faintest lines of iron.

The method adopted by Draper for obtaining the spectrum of oxygen consisted in the employment of a powerful spark in ordinary air. To obtain this spark the current from a dynamo running through the primary of a Ruhmkorf coil was suitably interrupted. By the use of an alternating machine and a step-up transformer, powerful sparks can be more readily obtained. Since the time of exposure with a grating of large dispersion is long, considerable heat is developed in the transformer from the powerful currents which are necessary to produce a spark of sufficient brilliancy. I have therefore modified the method in the following manner. The spark gap is enclosed in a suitable chamber, which can be exhausted. When the exhaustion is pushed to a certain point, the length of the spark can be increased ten or twenty times over its length in air, and a suitable spark for photographic purposes can therefore be obtained by the employment of far less energy in the transformer. A pressure of eight to ten inches of mercury in the exhausted vessel is sufficient. A quartz lens inserted in the wells of the exhausted chamber serves to focus the light of the spark on the slit of the spectroscope.

The following table gives the oxygen lines and iron lines in the same region of the spectrum.

O	Fe in Sun.	Intensity.
4631	4629·44	1
	4730·22	4
	4630·91	1
	4361·61	1
4656	4654·7	
	4657·71	
4683	4683·04	1
	4683·93	2
4601·5	4600·09	1*n*
	4601·8	1
	4602·11	4
4007	4604·84	1*n*
	4605·52	1
	4606·34	
	4607·79	6
4613	4611·38	8
	4613·35	4
	4614·29	1
4693·5	4691·52	6
	4696·97	1

The faintest iron lines are therefore not obliterated in the spaces where the oxygen lines should occur. If we examine the great absorption region about the K line, we find that between wave lengths 3930·29 and 3938·55 Rowland, it gives 8 lines which coincide with iron lines.

From the table of wave lengths of iron lines in the arc spectrum given in the report of the British Association for 1891, I find the following lines given between these limits.

3930·37*
3931·22*
3932·71*
3933·01*
3933·75
3934·47
3934 81*
3935·40*
3935·92*
3937·42*
2938·16
3938·59

The starred lines are probably the iron lines given by Rowland in his list of standard solar lines. The iron lines that are not starred apparently are obliterated in the great absorption band near the calcium line K.

Lord Salisbury, in his address before the British Association at Oxford, 1894, remarks: "Oxygen constitutes the largest portion of the solid and liquid substances of our planet, so far as we know it; and nitrogen is very far the predominant constituent of our atmosphere. If the earth is a detached bit, whirled off the mass, leaving the sun we cleaned him out so completely of his nitrogen and oxygen that not a trace of these gases remain behind to be discovered even by the sensitive vision of the spectroscope?"

Although we have not succeeded in detecting oxygen in the sun, it seems to me that the character of its light, the fact of the combustion of carbon in its mass, the conditions for the incandescence of the oxides of the rare earths which exist, would prevent the detection of oxygen in its uncombined state. Notwithstanding the negative evidence which I have brought forward, I cannot help feeling strongly that oxygen is present in the sun and that the sun's light is due to carbon vapor in an atmosphere of oxygen.

Jefferson Physical Laboratory.

Art. XXXIX.—*On the Determination of the Division Errors of a Straight Scale;* by Harold Jacoby.

1. Lying as it does at the base of all exact metrology, the above problem has received the attention of many investigators. Numerous methods have been devised and employed for its solution, the object generally sought being a result of sufficient accuracy accompanied with the minimum amount of labor. Probably the first investigation in which the highest precision was attained or even aimed at, was carried out by Hansen.* His method amounts to comparing the spaces of the scale under investigation, which we will call scale A, with a series of spaces marked upon an auxiliary scale B. This was done in such a way that every one-space of scale A was compared with an auxiliary one-space; every two-space of scale A, with an auxiliary two-space, etc. The method may of course be varied by using, instead of spaces on an auxiliary scale, a fixed interval between the two microscopes of a *comparateur.* In fact, Hansen's process really consisted in comparing *inter se* all the single spaces, two-spaces, three-spaces, etc., of scale A. The series of observations made in this way, Hansen treats by the method of least squares, giving a solution whose numerical application requires a very considerable amount of computation.

* Abh. d. math. phys. Classe der Kgl. Sächs. Gesell. d. Wissenschaften, vol. xv.

This method of Hansen appears to have received no material improvement until 1888. In that year, Gill, acting upon a suggestion made by Marth, began to determine the errors of the straight scales of the Cape heliometer. Gill employs an auxiliary scale B which is an exact duplicate of scale A. In fact, in the case of the heliometer, each of the two scales is used as an auxiliary for investigating the other. Instead of then comparing, as Hansen did, every one-space, two-space, etc., of scale A with *one* auxiliary one-space, two-space, etc., on scale B, Gill compares every one-space of scale A with every one-space of scale B; every two-space with every two-space; etc. This method must be regarded as an important extension of Hansen's. With comparatively little additional labor in the observations, it causes a considerable increase of precision in the results.

Precisely the same method of observation employed by Gill has been discussed very recently by Lorentzen,* and used in determining the errors of the Bamberg heliometer. He begins by applying the method of least squares rigidly to the reduction of the observations; but the numerical work required being very great, he concludes by recommending a slight departure from the rigid least square method of reduction. This brings him to a method which is identical with Gill's, both in the observations, and in the calculation of the division errors. They differ, however, in the calculation of the weights of the division errors determined for the several lines of the scale. Gill comes to the conclusion that all these division errors are determined with the same weight. This is not rigorously correct. Lorentzen does not come to the same conclusion; but as we shall see further on, he deduces a weight formula which is quite correct.

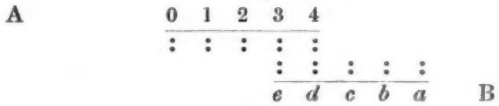
2. The method of Hansen, both in its original form, and as extended by Gill, in common with all other methods of determining division errors, has the defect just mentioned. The various lines are not determined with rigorously equal weight. Since, in general, there is no reason *a priori* why we should determine some of the lines more accurately than the others, a method which will produce true equality of weights for all the lines still remains a desideratum. Now the method of Gill would appear to be observationally exhaustive, since all possible combinations of spaces on the two scales have been compared. Nevertheless, the method may be observationally varied, the general weight greatly increased, and even the desired equality of weights may be produced, if we vary the precision with which the several comparisons between the two scales are effected. This need not increase the labor very

* Astronomische Nachrichten, 3134, 3236.

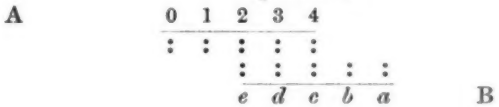
much, as we shall see further on. First, however, I will briefly describe Gill's method of observation and reduction. The latter admits of demonstration without resorting to extensive mathematical formulæ.

The scale under investigation, A, and the auxiliary scale, B, are supposed to be graduated as nearly alike as possible, and to be mounted so that one can be compared with the other. The observations are now effected in a series of separate operations, the diagrams given below showing how they would be arranged for a scale of four spaces.

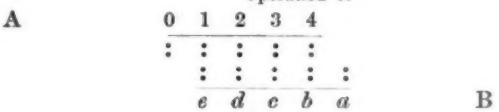
Operation 1.



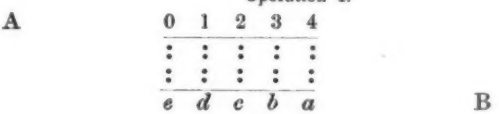
Operation 2.



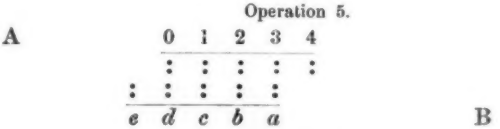
Operation 3.



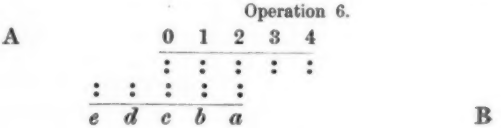
Operation 4.



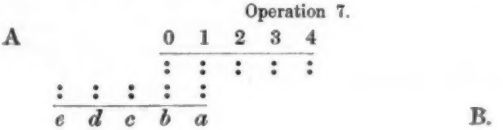
Operation 5.



Operation 6.



Operation 7.



Scale A is numbered 0, 1, 2, 3, 4; and scale B is numbered e, d, c, b, a, to avoid confusion. Operation 1 consists in placing scale B opposite scale A in such a way that division e comes opposite 3, and d opposite 4. The microscope of the *comparateur* is then brought over the divisions 3 and e, and readings are taken on each of these divisions. The microscope is then brought over the divisions 4 and d, and these are also read. The operation is then repeated in the reverse order, the scales remaining unmoved all the time. If we suppose the microscope readings to decrease as the readings of scale A increase, and if we put:

d_4 = excess of reading on division 4 over that on division d,
e_3 = excess of reading on division 3 over that on division e,

it is obvious that operation 1 furnishes the quantity:

$$e_3 - d_4,$$

or the excess of the space 3, 4 of scale A over the space e, d of scale B. In exactly the same way operation 2 furnishes the quantities:

$$d_3 - c_4 \text{ and } e_2 - d_3,$$

or the excesses of the spaces 2, 3 and 3, 4 over e, d and d, c respectively. Proceeding in this way, we may arrange the results of all the operations as in the following table:

TABLE I.

0, 1	1, 2	2, 3	3, 4	
			$(e_3 - d_4)$	Operation 1.
		$(e_2 - d_3)$	$(d_3 - c_4)$	" 2.
	$(e_1 - d_2)$	$(d_2 - c_3)$	$(c_3 - b_4)$	" 3.
$(e_0 - d_1)$	$(d_1 - c_2)$	$(c_2 - b_3)$	$(b_3 - a_4)$	" 4.
$(d_0 - c_1)$	$(c_1 - b_2)$	$(b_2 - a_3)$		" 5.
$(c_0 - b_1)$	$(b_1 - a_2)$			" 6.
$(b_0 - a_1)$				" 7.
K_1	K_2	K_3	K_4	

It will be seen that each of the quantities in parenthesis is the excess of one of the spaces of scale A over one of the spaces of scale B. Thus the first column contains the excesses of the space 0, 1 of scale A over each of the four spaces of scale B. Similarly the other columns contain the excesses of the spaces 1, 2; 2, 3; and 3, 4. Moreover the results of each separate operation will be found in the same horizontal line of the table. The quantities K_1, K_2, K_3, K_4, are the means of the quantities above them in the columns. Thus:

$$K_1 = \tfrac{1}{4}[(e_0 - d_1) + (d_0 - c_1) + (c_0 - b_1) + (b_0 - a_1)]$$

It is evident that K_1 is the excess of the space 0, 1 over the *true fourth part* of scale B, since it is the mean of the excesses of 0, 1 over the four constituent spaces of scale B. Consequently, if we assume scale B as standard, the space 0, 1 is too large by the quantity K_1, which we may express as follows:

Division error of line 1, scale $A_1 = K_1$

Similarly the space 1, 2 is too large by K_2, and therefore the space 0, 2 is too large by the quantity $K_1 + K_2$; or:

Division error of line 2, scale $A_2 = K_1 + K_2$

Similarly:

Division error of line 3, scale $A_3 = K_1 + K_2 + K_3$
Division error of line 4, scale $A_4 = K_1 + K_2 + K_3 + K_4$

Since we have assumed scale B as the standard, the quantity:

$$K_1 + K_2 + K_3 + K_4$$

or the division error of line 4 of scale A, is really the difference in length of the two scales; so if we put:

$$K_0 = \tfrac{1}{4}(K_1 + K_2 + K_3 + K_4),$$

K_0 will be the excess of the true average space of scale A over the true average space of scale B. Consequently, if we wish the division errors of scale A to be expressed in terms of that scale itself as a standard, we must write:

Division error of line $1 = K_1 - K_0$
Division error of line $2 = K_1 + K_2 - 2K_0$
Division error of line $3 = K_1 + K_2 + K_3 - 3K_0$
Division error of line $4 = K_1 + K_2 + K_3 + K_4 - 4K_0 = 0$

Table I also furnishes the corresponding division errors of scale B. If we take diagonal means as follows:

$$Q_d = \tfrac{1}{4}[(e_0 - d_1) + (e_1 - d_2) + (e_2 - d_3) + (e_3 - d_4)]$$
$$Q_c = \tfrac{1}{4}[(d_0 - c_1) + (d_1 - c_2) + (d_2 - c_3) + (d_3 - c_4)]$$
etc. etc.

we have:

Division error of line $d = -(Q_d - K_0)$
Division error of line $c = -(Q_d + Q_c - 2K_0)$
Division error of line $b = -(Q_d + Q_c + Q_b - 3K_0)$
Division error of line $a = -(Q_d + Q_c + Q_b + Q_a - 4K_0) = 0$

since, necessarily,

$$K_1 + K_2 + K_3 + K_4 = -(Q_d + Q_c + Q_b + Q_a)$$

Generalizing these formulæ we have for the division error of the line numbered m on scale A, supposed to have $n+1$ lines, numbered from 0 to n, the following:

$$\left.\begin{aligned} K_0 &= \frac{1}{n}\sum_1^n K \\ \text{Division error of line } m &= \sum_1^m K - mK_0 \end{aligned}\right\} \qquad (1)$$

And for the other scale,

$$\text{Division error of line } m = -\left(\sum_d^m Q - mK_0\right)$$

3. The above is Gill's method, substantially in the form described in the Monthly Notices (vol. xlix, p. 110); though the way in which it is presented has been somewhat modified. The formulæ (1) are the same as Lorentzen's final formulæ, given in Astr. Nach., 3336.

The next step is to calculate the weights of the division errors determined. This can be done very easily, if we notice in Table I that the sum of any number of consecutive parentheses in the same horizontal line is known with the same precision as any one parenthesis alone. Thus the quantity:

$$(e_0 - d_1) + (d_1 - c_2) + (c_2 - b_3)$$

is known with the same precision as the equivalent quantity:

$$e_0 - b_3$$

This circumstance will of course affect the sums of the K's, the mean error of

$$K_1 + K_2$$

for instance, being by no means as great as

$$\sqrt{2}\,(\text{mean error of } K_1),$$

as it would be if K_1 and K_2 were independent. Now let us put:

ε = mean error of any of the observed quantities, as c_1, b_2, etc., which are supposed to be all observed with equal precision.
A_m = division error of line m on scale A.
$s_m = b_m + c_m + d_m + \ldots,$

so that s_m is the sum of all the letters except the first and last, after each has received the subscript m. Then we get at once from equations (1)

$$A_m = \frac{n-m}{n}\sum_1^m K - \frac{m}{n}\sum_{m+1}^n K$$

Also we see from Table I that

$$n\sum_1^m K = s_0 - s_m + (e_0 + e_1 + \ldots + e_{m-1}) - (a_1 + a_2 + \ldots + a_m)$$

$$n\sum_{m+1}^n K = s_m - s_n + (e_m + e_{m+1} + \ldots + e_{n-1}) - (a_{m+1} + a_{m+2} + \ldots + a_n)$$

Substituting these values in the previous equation gives:

$$A_m = \frac{n-m}{n^2}\left[s_0 + \sum_0^{m-1} e - \sum_1^{m} a \right] + \frac{m}{n^2}\left[s_n - \sum_m^{n-1} e + \sum_{m+1}^{n} a \right] - \frac{s_m}{n}$$

This equation is not intended for calculating A_m, since equation (1) is more convenient for that purpose. But in the present equation, all the quantities are independent, so that it can be used at once for getting E, the mean error of A_m. Since ε is the mean error of any one of the observed quantities, we shall have:

$$\text{(mean error of } s_0)^2 = (n-1)\varepsilon\varepsilon$$
$$\text{(mean error of } \sum_0^{m-1} e)^2 = m\varepsilon\varepsilon$$
$$\text{(mean error of } \sum_m^{n-1} e)^2 = (n-m)\varepsilon\varepsilon$$
$$\text{(mean error of } s_m)^2 = (n-1)\varepsilon\varepsilon$$
$$\text{etc.} \qquad\qquad \text{etc.}$$

Consequently,

$$EE = \left\{ \left[\frac{n-m}{n^2}\right]^2 \left[n-1+m+m \right] \right\} \varepsilon\varepsilon$$
$$+ \left\{ \left[\frac{m}{n^2}\right]^2 \left[n-1+n-m+n-m \right] + \frac{n-1}{n^2} \right\} \varepsilon\varepsilon$$
$$= 2\left[n^2(n-1) + m(n-m) \right] \frac{\varepsilon\varepsilon}{n^4}$$

If, therefore, we assume our unit of weight such that:

$$\varepsilon\varepsilon = 1$$

we shall have for computing the weight P_m of line m on scale A, the equation:

$$\frac{1}{P_m} = \frac{2(n-1)}{n^2} + \frac{2m}{n^4}(n-m) \qquad (2)$$

$\frac{1}{P_m}$ has a maximum value for:

$$m = \frac{n}{2}$$

We therefore have:

$$\frac{1}{P}\ \text{(maximum)} = \frac{2n-\frac{3}{2}}{n^2} \qquad (3)$$

The minimum value of $\frac{1}{P_m}$, subject of course to the condition that m may only vary from 1 to $n-1$, will occur when:

$$m = 1 \text{ or } m = n-1$$

In either case:

$$\frac{1}{P}\ \text{(minimum)} = \frac{2(n-1)(n^2+1)}{n^4} \qquad (4)$$

The difference, therefore, is:

$$\frac{1}{P}\ (\text{maximum}) - \frac{1}{P}\ (\text{minimum}) = \frac{\frac{1}{2}(n-2)^2}{n^4}$$

The formula obtained by Lorentzen for computing P_m is, allowing for the difference of notation (Astr. Nach., 3134, Eq. 15):

$$\frac{1}{P_m} = \frac{2}{n^2}(n-1) + \frac{2m}{n^4}(n-m)$$

which agrees with equation (2) just obtained. But Lorentzen's value for the weight of a quantity he calls δ, which equals the excess of the true average space of scale A over the true average space of scale B, is not quite exact. In our notation this excess is $\frac{1}{n}K_o$, and as we have seen, it is equal to:

$$\frac{1}{n^2}\ (\text{the sum of all the parentheses in Table I}).$$

We have also seen that the sum of all the parentheses in any horizontal line of Table I, has for the square of its mean error the quantity:

$$2\varepsilon\varepsilon$$

And, as there are $2n-1$ horizontal lines, the sum of the whole table has for the square of its mean error:

$$2(2n-1)\varepsilon\varepsilon$$

Therefore the square of the mean error of δ is:

$$\frac{2(2n-1)}{n^4}\varepsilon\varepsilon$$

and the weight of δ, $\varepsilon\varepsilon$ being taken as unity, is:

$$\frac{n^4}{2(2n-1)}$$

which may be written:

$$\frac{n^3}{4-\frac{2}{n}}$$

Lorentzen gets for the same quantity the slightly incorrect value:

$$\frac{n^2}{4}$$

In Table II, which will be given further on, are contained the maximum and minimum weights obtained in Gill's method for various values of n. The table is computed by means of equations (3) and (4). When n is an even number, the maximum weight applies to the middle line of the scale; and when

n is an uneven number, it applies to either of the two lines nearest the middle of the scale.

4. Having now described Gill's method, I shall proceed to show how it may be improved very materially. For this purpose, let us resume the equation:

$$A_m = \frac{n-m}{n^2}\left[s_0 + \sum_0^{m-1} e - \sum_1^{m} a \right] + \frac{m}{n^2}\left[s_n - \sum_m^{n-1} e + \sum_{+1}^{n} a \right] - \frac{s_m}{n}$$

Now let us suppose that the various observed quantities contained in Table I, have been determined with different weights as follows:

$$\text{Weight of } a_0 = \frac{1}{a'_0}$$

$$\text{Weight of } c_2 = \frac{1}{c'_2}$$

etc. etc.

In other words, let us indicate the number of times each letter is observed by the reciprocal of that letter *primed*. Then if we put:

$$s'_m = b'_m + c'_m + d'_m + \ldots$$

following the analogy of s_m, already employed, we shall have:

$$(\text{mean error of } s_0)^2 = s'_0 \varepsilon\varepsilon$$

$$(\text{mean error of } s_m)^2 = s'_m \varepsilon\varepsilon$$

$$(\text{mean error of } \sum_0^{m-1} e)^2 = \varepsilon\varepsilon \sum_0^{m-1} e'$$

etc. etc.

Consequently we shall have for computing the square of the mean error of line m on scale A, assuming $\varepsilon\varepsilon = 1$:

$$n^4(\mathrm{EE})_m = n^4 \frac{1}{P_m} = n^2 s'_m + (n-m)^2\left[s'_0 + \sum_0^{m-1} e' + \sum_1^{m} a' \right] + m^2\left[s'_n + \sum_m^{n-1} e' + \sum_{m+1}^{n} a' \right] \qquad (5)$$

This equation may be used in a very simple way for strengthening Gill's method. Let us put the weights of all the exterior quantities in Table I equal to each other, i. e., let us put:

$$\frac{1}{b'_0} = \frac{1}{c'_0} = \frac{1}{d'_0} = \frac{1}{e'_0} = \frac{1}{e'_1} = \frac{1}{e'_2} = \frac{1}{e'_3} = \frac{1}{d'_4} = \frac{1}{c'_4} = \frac{1}{b'_4} = \frac{1}{a'_4} = \frac{1}{a'_3} = \frac{1}{a'_2} = \frac{1}{a'_1}$$

and suppose any one of these quantities to be represented by $\frac{1}{q}$. In other words, let us observe every comparison between the two scales in which either of the four end lines appears $\frac{1}{q}$

times instead of once, and use the mean in the further computations. We then have, since $\varepsilon\varepsilon = 1$:

$$s'_m = n-1,\ s'_0 = (n-1)q,\ s'_n = (n-1)q$$

$$\sum_0^{m-1} e' = mq,\ \sum_1^{m} a' = mq,\ \sum_m^{n-1} e' = (n-m)q,\ \sum_{m+1}^{n} a' = (n-m)q,$$

So that if we put all the other weights equal to unity, equation (5) becomes:

$$\frac{1}{P_m} = \frac{1}{n^2}(n-1) + \left[\frac{1}{n^2}(n-1) + \frac{2m}{n^4}(n-m\right]q \qquad (6)$$

This equation agrees with (2) if we put unity for q.

I shall call Gill's method, when modified in the manner just explained, method 1. In Table II given below, will be found the maximum and minimum weights belonging to method 1, placed for comparison next to those belonging to Gill's method. In order to bring out more clearly the advantage of method 1, I have also put in the table the total number of observations required for carrying out Gill's method, and the additional number required for method 1. This number is:

For Gill's method, $(n+1)^2-2$

Additional for method 1, $(4n-2)\left(\frac{1}{q}-1\right)$

In computing the column "Time used" I have taken as the unit the time required to make one observation in Gill's method. I have then assumed that the additional observations of method 1 each require only one-fourth as much time, since they simply consist in additional settings after the microscope, etc., have been brought into position and adjusted. In computing the table, I have put:

$$\frac{1}{q} = 4,$$

which is equivalent to observing all the comparisons involving the end lines four times. It does not seem desirable to carry the number of observations beyond four for any one comparison, since it is doubtful if the mean of a large number of observations of this kind really possesses a weight corresponding to that number.

For the sake of comparison, I set down here the theoretical weights which would result from a rigid least square discussion of the observations in Gill's method, according to Lorentzen.

	Weight.	
n	Max.	Min.
3	2·15	2·15
4	2·77	2·68
5	3·35	3·19
6	3·99	3·69
10	6·49	5·74

It will be seen that these weights are nearly the same as those obtained in Gill's own method of reduction.

TABLE II.

n	Gill Method. Weight.		Method 1. Weight.		Max. Weight. Min. Weight.		No. of Obs.		Time used (arbitrary unit).		Min. Wt. × 10^2 Time used.	
	Max.	Min.	Max.	Min.	Gill	1	Gill	addit. 1	Gill	1	Gill	1
3	2·03	2·02	3·45	3·44	1·00	1·00	14	30	14	21·5	14·3	16·0
4	2·49	2·44	4·13	4·10	1·02	1·01	23	42	23	33·5	10·5	12·2
5	3·00	2·95	4·93	4·88	1·02	1·01	34	54	34	47·5	8·5	10·2
6	3·47	3·40	5·65	5·62	1·02	1·01	47	66	47	63·5	7·1	8·8
7	4·08	4·00	6·62	6·58	1·02	1·01	62	78	62	81·5	6·4	8·1
8	4·39	4 31	7·09	7·04	1·02	1·01	79	90	79	101·5	5·6	6·9
9	5·15	5·05	8·33	8·26	1·02	1·01	98	102	98	123·5	5·1	6·7
10	5·49	5·41	8·93	8 85	1 02	1·01	119	114	119	147·5	4·3	6·0
15	8·06	7·94	12·90	12·82	1·02	1·01	254	174	254	297·5	3·2	4·3
20	10·53	10·42	16·86	16·78	1·01	1·01	439	234	439	497·5	2·4	3·4

The last two columns of Table II bring out very clearly the advantage of method 1 over Gill's. It may be objected that these columns depend upon the somewhat arbitrary assumption that the additional observations require only one-fourth the time needed for the first ones. But it should be noted that even without this assumption, these columns would show an increasing advantage for method 1, as soon as n becomes larger than 10 or 12. The same would be true even for the smaller values of n if we were to put $\frac{1}{q}$ equal to 2 or 3 instead of 4. But the assumption seems fully justified by the experience gained by Dr. Gill and others in investigating the scales of the Cape heliometer.

5. The above method 1 leaves very little to be desired on the score of variation in the weight with which the several division errors are determined. Consequently the investigation of a method which will make these weights all equal is of interest chiefly from the theoretical point of view. Still an occasion might possibly arise when it would be worth while to take the extra trouble necessary to bring about this equality of weights. This can be done by the following method, which we will call method 2. Let us resume equation (5):

$$n^4 \frac{1}{P_m} = n^2 s'_m + (n-m)^2 \left[s'_0 + \sum_0^{m-1} e' + \sum_1^{m} a' \right]$$
$$+ m^2 \left[s'_n + \sum_m^{n-1} e' + \sum_{m+1}^{n} a' \right] \qquad (5)$$

and put $m+1$ for m in it. This gives:

$$n^4 \frac{1}{P_{m+1}} = n^2 s'_{m+1} + (n-m-1)^2 \left[s'_0 + \sum_0^{m} e' + \sum_1^{m+1} a' \right]$$
$$+ (m+1)^2 \left[s'_n + \sum_{m+1}^{n-1} e' + \sum_{m+2}^{n} a' \right]$$

In order to bring about equality of weights, we have only to make:

$$n^4 \frac{1}{P_m} = n^4 \frac{1}{P_{m+1}}$$

If we do this, and let $\frac{1}{q}$ have the same signification as before, we get, after some simplification:

$$s'_m - s'_{m+1} = \frac{2q}{n^2} [n-1+2m(n-2)] \qquad (7)$$

This equation shows that the sum of the reciprocals of all the weights (except the top and bottom weights) in any column of Table I exceeds that in the following column by the quantity:

$$\frac{2q}{n^2} [n-1+2m(n-2)]$$

And if this equation be satisfied for all values of m from $m=1$ to $m=n-2$, the division errors will be determined with equal weight. If we substitute successively 1, 2, 3, . . , $n-2$ for m in equation (7), we get a series of quantities in arithmetical progression. Summing this we derive:

$$s'_1 - s'_m = -\frac{2q}{n^2}(n-1) + \frac{2q}{n^2} [m(n-2)+1]m \qquad (8)$$

This equation shows that s'_1 can never exceed s'_m by a quantity greater than $2qn$; and since an inspection of Table I shows that $s'_1 - s'_m$ cannot possibly be made greater than $n-1$, it follows that $2q$ cannot be taken greater than unity, or q greater than $\frac{1}{2}$. We have already explained that it is not desirable to make q less than $\frac{1}{4}$. It will therefore be best to put as before:

$$q = \tfrac{1}{4}$$

It is obviously desirable to make:

$$s'_1 = n-1$$

or in other words, to observe once all the quantities in Table I that have the suffix 1, except the top and bottom ones e_1

and a_1. By means of equation (8) we can then find out how many times to observe the quantities having the suffix m. Of course we cannot apply equation (8) rigorously, as that would make it necessary to observe some of the quantities a fractional number of times. In fact, if we observe even one of the quantities in column m twice instead of once, we shall have made:

$$s'_1 - s'_m = \tfrac{1}{2}$$

and we cannot possibly make it less than $\frac{1}{2}$, unless we leave it zero. It will therefore be best to begin to make

$$s'_1 - s'_m = \tfrac{1}{2}$$

as soon as its theoretical value exceeds $\frac{1}{4}$, and to continue it $\frac{1}{2}$, until its theoretical value reaches $\frac{3}{4}$. We can then make it 1, until its theoretical value exceeds $\frac{5}{4}$, etc. To do this conveniently, we must solve equation (8) for m, after putting $q = \frac{1}{4}$. This gives, finally:

$$m = \frac{\sqrt{4(n-1)\,(n-2) + 8n^2(n-2)\,(s'_1 - s_m') + 1} - 1}{2(n-2)} \qquad (9)$$

We shall now apply this to an example. Suppose $n = 4$, as in Table I. Equation (9) then becomes:

$$m = \frac{\sqrt{25 + 256(s'_1 - s'_m)} - 1}{4}$$

from which we get:

for $s'_1 - s'_m = \frac{1}{4}$	$m = 2,\ 1$
" $s'_1 - s'_m = \frac{3}{4}$	$m = 3,\ 4$

We should, therefore, in Table I begin to observe one of the interior quantities twice for $m = 3$. For this purpose we might select either b_3 or c_3.

The above method 2 renders all the weights almost exactly equal. What the common weight is can be computed from equation (5). Since the weight is always the same, we may put in equation (5):

$$m = 1,\ s'_m = n-1$$

We, therefore, also have:

$s'_0 = (n-1)q$	$s'_n = (n-1)q$
$\sum_0^{m-1} e' = q$	$\sum_m^{n-1} e' = (n-1)q$
$\sum_1^{m} a' = q$	$\sum_{m-1}^{n} a' = (n-1)q$

Consequently:

$$\frac{1}{P} = \frac{n-1}{n^2} + \left[\frac{(n-1)\,(n^2-1)}{n^4} + \frac{3(n-1)}{n^4}\right] q$$

which does not differ very much from the weight obtained in method 1.

6. As an example of the use of method 1, I have caused two of my students, Messrs. Schlesinger and Ling, to make a determination of the non-periodic errors of one of the screws of the double microscope of the Repsold machine for measuring photographs at Columbia College Observatory. The method is admirably adapted for this purpose, and I am not aware that it has been used elsewhere for examining screws. It is merely necessary to take readings on the successive divisions of the millimeter scale of the machine, arranging them in accord with the scheme explained above. Such a set of readings is set down in Table A below, the number attached to each screw-reading being the weight of that reading, or the number of times the line of the scale was bisected at that point. The exterior quantities have been observed three times, instead of four, as recommended in this paper. This was done to save time. Table B is obtained from Table A by taking the differences of the successive numbers, and corresponds exactly to Table I given on page 336. In Table C the K's are set down, and their summation gives the corrections of the screw at the points 5, 7, 9, 11, 13, 15, revolutions. In column four of the table the necessary corrections are applied to give results in terms of the screw as a standard, instead of the scale. This is done by means of equation (1). Column five contains the corrected division errors, as determined by the observer S. Columns six and seven contain the results of the observations by L. and of a second set of observations by S. The last column gives the mean. In all these tables, unity in the fourth decimal place corresponds to one-twentieth of a micron on the scale. It will be noticed that in one case only does the difference from the mean amount to half a micron, or $\frac{1}{50000}$ of an inch on the scale. This implies that in measuring any object with this microscope, we need not fear errors of greater amount than $\frac{1}{50000}$ inch, on account of the non-periodic errors of the screw. It is to be noted also that this method gives the errors of the screw without the assumption of any law of error, while in many investigations by other methods it has been customary to assume that the non-periodic screw errors could be represented by a parabolic curve.

TABLE A.

Horizontal argument : Scale readings.

	78mm	77mm	76mm	75mm	74mm	73mm
Operation 1	13·0027 (3)	14·9983 (3)				
" 2	11·0023 (3)	13·0005 (1)	14·9960 (3)			
" 3	9·0070 (3)	11·0088 (1)	13·0075 (1)	15·0038 (3)		
" 4	7·0062 (3)	9·0075 (1)	11·0055 (1)	13·0075 (1)	15·0013 (3)	
" 5	4·9945 (3)	6·9935 (1)	8·9940 (1)	10·9985 (1)	12·9950 (1)	14·9917 (3)
" 6		5·0045 (3)	6·9995 (1)	9·0035 (1)	11·0035 (1)	13·0022 (3)
" 7			4·9970 (3)	6·9980 (1)	9·0000 (1)	10·9982 (3)
" 8				5·0013 (3)	7·0015 (1)	8·9992 (3)
" 9					5·0003 (3)	7·0002 (3)

TABLE B.

Excess of Two Revolutions of Screw over Space on Scale.

	Screw. 5–7	Screw 7–9	Screw 9–11	Screw 11–13	Screw 13–15
Scale 78–77	−·0010	+·0013	+·0018	−·0018	−·0044
" 77–76	−·0025	+·0005	−·0020	−·0013	−·0045
" 76–75	+·0010	+·0050	+·0045	+·0020	−·0037
" 75–74	+·0002	+·0020	−·0005	−·0035	−·0062
" 74–73	−·0001	−·0023	−·0018	−·0013	−·0033
Means	−·0005 K_1	+·0013 K_2	+·0004 K_3	−·0012 K_4	−·0044 K_5

TABLE C.

Screw	K	ΣK	$-mK_0$	Obs'r. S. Div. error	Obs'r. L. Div. error	Obs'r. S. 2d set Div. error	Mean
5	·0000	·0000	·0000	·0000	·0000	·0000	·0000
7	−·0005	−·0005	+·0008	+·0003	+·0016	−·0002	+·0006
9	+·0013	+·0008	+·0017	+·0025	+·0018	+·0016	+·0020
11	+·0004	+·0012	+·0025	+·0037	+·0031	+·0027	+·0032
13	−·0012	·0000	+·0036	+·0036	+·0036	+·0033	+·0035
15	−·0044	−·0044	+·0044	·0000	·0000	·0000	·0000

These division errors are to be subtracted from observed readings of the screw.

Columbia University Observatory, New York.

Art. XL.—*Studies upon the Cyperaceæ;* by Theo. Holm. (With Plate IX.)

I. On the monopodial ramification in certain North-American species of *Carex.*

Two kinds of ramification are known to be represented in the genus *Carex:* the sympodial and the monopodial. The first of these is the most common, and species which exhibit this ramification show only the development of one single axis, which in its first year of growth merely develops leaves, until it finally, two or three years later, passes over into a flower-bearing stem. In this case the leaves and the flower-bearing stem are both developed from the same bud. But in the other kind of ramification, the monopodial, two special forms of buds develop, the main one of which continues to develop leaves, while the floral buds are constantly lateral. In this case there are two different axes, and species which possess such kind of ramification are, therefore, biaxial.

These two forms of ramification are easily recognized in our species of *Carex.* The sympodial shows us a central flower-bearing stem, the base of which is surrounded by more or less faded leaves from the previous year, while the monopodial shows a central leafy shoot with a number of laterally developed flower-bearing stems. The terminal shoot, when purely vegetative, can continue to grow for several years, and when it finally dies off, one or more vegetative buds develop from the axils of its leaves, which grow out and repeat the same kind of ramification. It is now interesting to note, that the monopodial ramification is only known as very rare in the genus *Carex.*

The German botanist Wydler deserves the credit for being the first one to observe it in *Carex*, and he described it as characteristic of two European species: *C. digitata* L. and *C. ornithopoda* Willd.* Some years later Alexander Braun attributed the same form of ramification to *Carex pilosa* Scop., *C. pendula* Huds. and *C. strigosa* Huds.† It is difficult to know, however, whether this statement of Braun is really correct. Doell has, at least, contradicted him so far as concerns *C. strigosa* and *C. pilosa*,‡ and he states that by examining a large number of specimens of *C. strigosa*, the flower-bearing stems were constantly found to be central, and that he was unable to detect any central vegetative shoot in *C. pilosa.*

* Ueber die Achsenzahl der Gewächse, Bot. Ztg., 1844.

† Das Individuum der Pflanze in seinem Verhältniss zur Species, Abhdlg. d. k. Acad. d. Wissensch, Berlin, 1853, p. 90.

‡ Flora von Baden, Carlsruhe, 1857.

Celakovsky, however, has supported Braun's opinion, and declared Doell's statement to be incorrect in regard to *C. pilosa*.* The flowering stems are actually lateral in this species, but the central vegetative axis dies off very soon. Only one more species has been added to these, namely *C. globularis* L., by Callmé.†

If we now consider our North-American species, it is surprising to see that the systematic authors keep perfectly silent in this matter, although Boott has illustrated it so exceedingly correct in several of his figures.‡

The monopodial ramification is very well represented in this country, and exists in several of our commonest species. It is characteristic of all the species, which Bailey§ has enumerated under the group "*Laxifloræ*" of Kunth, viz: *C. laxiflora* Lam. and its varieties, *C. Hendersoni* Bailey, *C. laxiculmis* Schw., *C. ptychocarpa* Steud., *C. digitalis* Willd., *C. Careyana* Torr., *C. plantaginea* Lam. and *C. platyphylla* Carey; besides that it, also, exists in the remarkable species *C. Fraseri* Andrews of the "*Physocephalæ*." We have examined several specimens of these species and the character appears to be constant.

The accompanying plate (IX, fig. 1) illustrates this ramification as shown in *C. platyphylla*, the specimen collected in the early spring. We see here a perennial vegetative shoot, the base of which is surrounded by a number of buds, which will develop into flower-bearing stems during the same spring. These floral buds are all developed in the axils of old leaves, which are situated on the same axis as those of the upper part of the shoot, which are now in their prime of growth. By examining the axils of the younger leaves, we find, also, buds, which will develop into floral shoots one year later. It cannot, however, be decided with any certainty how long the vegetative shoot can continue its growth, but it seems, at least in the species enumerated above, that it can persist for more than three years. *C. digitalis* forms perhaps an exception, since the vegetative shoot in most of the specimens examined did not seem to have persisted for a longer time than two years. The growth of the individual is, however, as mentioned above, secured by the development of a few lateral buds next to the floral ones. There are some other species of *Carex*, which probably are monopodial like the above mentioned. These are, e. g., *C. pubescens* Muhl., *C. oligocarpa* Schk., *C. grisea* Wahl., *C. gracillima* Schw. and *C. arctata* Boott. These

* Pflanzenmorphologische Mittheilungen, Lotos, vol. xiv, 1864, p. 20.

† Ueber zweigliedrige Sprossfolge bei den Arten der Gattung *Carex*, Berichte d. deutsch. botan. Gesellsch, vol. v, 1887.

‡ Illustrations of the genus Carex, London, 1858–67.

§ A preliminary synopsis of North-American Carices, Proceed. Am. Acad. of Arts and Sciences, April 14, 1886.

species do not show, however, any persistent central vegetative shoot, but the flower-bearing stems appear, nevertheless, as if they were lateral. We might suppose in these cases that the age of the vegetative shoot does not exceed one year. *C. gracillima* and *C. arctata* are perhaps to be compared with the above described *C. pilosa*.

A marked characteristic of these monopodial species is that the floral shoots are surrounded at their base by scale-like leaves. In the sympodial the flower-bearing stems are commonly, if not always, surrounded by proper leaves with closed sheaths and long, green blades. The monopodial ramification is, therefore, represented in this country by a number of species, most of which are common and abundantly occurring. These species are not exclusively southern forms, since several of them extend as far north as Canada, according to Macoun.* The character of being monopodial does, therefore, not seem to be favored by any special climate; we can only state that it seems to be especially well represented on this side the Atlantic, and we might perhaps feel justified to add, that it is prevalent among our sylvan forms. Purely vegetative shoots are, however, not exclusively connected with the monopodial ramification. There are among the sympodial species some, which yearly develop assimilatory shoots, which die off in the first year of their growth. Such species show, then, besides the flowering stems, a number of very densely leaved shoots, for instance *C. tribuloides* Wahl. with its varieties, *C. Muskingumensis* Schw., *C. straminea* Willd. and *C. Sartwelli* Dewey. These sterile shoots develop sometimes, as figured on our Plate IX (fig. 2, by *b*) small lateral buds in the axils of their leaves, which, however, die off at the same time as the entire shoot itself. It is, at the same time, interesting to observe the base of the shoots, both the floral and vegetative, of *C. tribuloides* and *C. Muskingumensis* (Plate IX, figs. 2 and 3). We find here distinct internodes which are not hidden within the sheaths of leaves, but which are free to quite a considerable extent. These basal internodes are even sometimes geniculate and show the nodes almost as distinct as in the *Gramineæ*. But otherwise, as it is stated in the Manuals, etc., the basal internodes in *Carex* are very short and perfectly invisible on account of the densely crowded leaves.

Washington, D. C., February, 1896.

EXPLANATION OF PLATE IX.

FIGURE 1.—Specimen of *Carex platyphylla* at its vernal stage, showing a central vegetative shoot and a number of lateral floral ones. Natural size.

FIGURE 2.—Specimen of *Carex tribuloides*, showing one floral and one vegetative shoot. The base shows distinct internodes. About one-third of the natural size.

FIGURE 3.—Base of a floral shoot of *Carex Muskingumensis* with long internodes and distinct nodi. Natural size.

* Catalogue of Canadian plants, Part IV, Endogens, Montreal, 1888.

ART. XLI.—*The Bearpaw Mountains of Montana. First Paper*; by WALTER HARVEY WEED and LOUIS V. PIRSSON.

[Continued from p. 301.]

Beaver Creek Core.

A FEW miles north of Bearpaw Peak the deeply trenched valley of Beaver Creek cuts through an igneous center or intrusive stock of granular rock which presents a highly interesting example of an igneous mass which, intruded into sedimentary strata, has there experienced a differentiation in place, producing a gradational series of rock types. An excellent illustration of this process, already described by the authors,* occurs at Yogo Peak in the Little Belt Range, the front of the Rocky Mountain Cordillera, 120 miles to the southward, and it is interesting to find similar rock types repeated here. The brief visit made to the Beaver stock did not permit of a thorough study of the mutual relations of the different types involved, but the most basic rocks were found near the periphery of the intrusion, which is in accord with the usual occurrence of such rocks.

The locality is accessible by wagon road from Fort Assiniboine to the prospect claims located on several small metalliferous veins occurring in the stock. The tract is one of gently contoured, grassy summits trenched by abrupt and deep drainage ways. The topographic relief affords no hint of the presence of the massive rock, and the slopes are not scenically attractive. The accompanying diagram (fig. 4) represents an

FIG. 4. Section through intruded stock at the head of Beaver Creek, Bearpaw Mountains.

ideal east-and-west section through the stock. The intrusion is laccolithic in character, the sedimentary rocks dipping away from it in every direction, as shown in the figure. The exposed surface of the intrusion is about a mile across. The sedimentary rocks are highly altered and metamorphosed in the contact zone, and as usual these hardened strata resist erosive agencies better than the granular rock forming the higher

* Weed and Pirsson, Igneous Rocks of Yogo Peak, this Journal, l, 467, 1895.

ridges and crests about the stock. The rocks of the contact zone are well exposed on the south side of the core, where they form the cliffs on either side of Beaver Creek, dipping up stream and away from the stock at 20°, which becomes but 15° farther away from the core. Detached masses of the altered sedimentary rocks are in one place found resting upon the granular rock, as shown in fig. 4. On the crest of the spur showing these detached masses the line of contact is seen to be somewhat irregular, and the igneous rock breaks through the baked sedimentaries in chimney-like masses. The western border of the stock shows the best exposures of the contact zone. Above the uniform crest of a ridge of massive rock, the slopes of altered sedimentary strata rise abruptly to a high ridge forming the divide between the waters of Beaver Creek and the stream to the west. The ridge is formed of highly altered, hardened, metamorphosed shales forming adinoles of white and light creamy tones of brown, green, lavender and pink, together with sandstones altered to dense compact quartzites, the beds dipping at 20° away from the stock. The metamorphic influence of the igneous rock is noticeable in a zone about a half mile in width.

The massive rock shows considerable variation in character. A rather finely granular, even-grained, syenitic rock showing equal proportions of feldspathic and of ferromagnesian minerals, forms the main body of the mass, but this passes rapidly in some places into a dark, highly basic type, and on the northern boundary a highly feldspathic variety is seen, a syenite, which as it is the most acidic type occurring at this core will be considered first.

Beaver core syenite.—This variety occurs on the north side of a branch creek, from the east, near a miner's cabin. It forms a debris pile of rudely platy blocks, is hard and tough, ringing under the hammer, and breaking with difficulty. The blocks are lichen-covered, but the rock is quite fresh though stained with iron leachings near the surface. On a freshly fractured surface the rock is seen to be fine grained, evenly granular, and compact. The color is gray, slightly stained with iron rust. The rock is essentially feldspathic, and of somewhat aplitic aspect. Close examination shows certain feldspars developed with a tabular habit which give long cleavage planes with parallel arrangement. This and the "Schlieren" seen in the field show a rude flow-structure. Examined with the lens, it is seen to be composed mainly of light-colored feldspar, with a few inconspicuous small spots of green pyroxene.

In thin section under the microscope the following minerals are found: *alkali feldspar*, *augite*, *iron ore*, *quartz*, a very little *biotite*, *hornblende*, and *titanite*.

The *augite* is a clear green diopside. It occurs in small anhedral grains and there is very little of it. The *iron ore* is about equal in amount; of the *biotite* only a few shreds have been seen. *Titanite* is rare.

The *feldspar* forming the main constituent is entirely of the alkaline series; no plagioclase feldspars have been found. In the main it has a rude, thick, tabular habit on *b*(010), giving square or rectangular cross sections whose interstices are filled by smaller grains and quartz. It shows throughout a pronounced and beautiful microperthite structure, more developed on the boundaries and thus fringing the sections with palisade-like edges. The remaining feldspar consists also of varying mixtures of the albite and orthoclase molecules, giving spotted, cloudy effects in polarized light. At times the interlaminated lamellæ are so fine as to be seen only with high powers. The feldspars in fact present most perfectly the varying effects so well described by Brögger and by Rosenbusch in their articles on the alkali feldspars. The numerous contacts with quartz show that they have always, in all positions, a lesser index of refraction than the quartz. In a section parallel to *b*(010) an obtuse positive bisectrix emerges, and in some areas measured from the trace of the good cleavage *c*(001) the extinction-angle is 7° plus; these are of orthoclase. In other areas it rises to 19° which are albite; these are marked by a higher birefraction. Others give varying angles between them and are mixtures; on this face the albite interlaminations follow the direction of a very steep dome. In sections perpendicular to *b*(010) the albite patches show often the albite twinning whose maximum extinction-angle was measured at 15° on either side of the twinning line. We believe that these feldspars were once homogeneous anorthoclase and have split up into these variable masses through secondary processes. The average composition is given after the analysis.

The *quartz* fills small spaces left between the other components. It frequently contains vast quantities of slender hair-like interpositions which are indeterminable, but are believed to be of rutile like those found in certain granites.

The analysis of the rock by Dr. H. N. Stokes yielded the results shown on the following page.

	I.	II.	III.	I*a*.
SiO_2	68·34	66·22	65·54	1·139
Al_2O_3	15·32	16·22	17·81	·149
Fe_2O_3	1·90	1·98	·74	·012
FeO	·84	·16	1·15	·012
MgO	·54	·77	·98	·014
CaO	·92	1·32	1·92	·016
Na_2O	5·45	6·49	5·55	·089
K_2O	5·62	5·76	5·58	·060
H_2O—110°	·15	·08	·54	
H_2O+110°	·30	·24		
TiO_2	·21	·22	·11	
MnO_2	·07	trace	trace	
BaO	·08	·29	not det.	
SrO	·04	·06	not det.	
Li_2O	none	trace	trace	
P_2O_5	·13	·10	trace	
Cl	·04	·04	----	
Fl	none	trace	----	
SO_3	----	·02	----	
	99·95	99·97	99·92	
	·01	·01		
	99·94	99·96		

I. Quartz syenite, Beaver Creek stock, Bearpaw Mountains, H. N. Stokes anal.

II. Quartz syenite porphyry, Gray Butte stock, Bearpaw Mountains, H. N. Stokes anal.

III. Quartz syenite, Highwood Peak, Highwood Mountains, L. V. Pirsson and W. L. Mitchell anal.

I*a*. Molecular proportions of No. I.

The low lime, iron, and magnesia show that the rock belongs in the alkaline series. A couple of analyses are quoted for comparison from the first part of this paper. In I*a* are given the molecular proportions of the essential oxides. These show some interesting features in their mutual relations and may be computed into the minerals shown in the section as follows:

K_2O = ·060 = 1	Orthoclase	Na_2O = ·089 = 1	Albite	Or.	= 33·9
Al_2O_3 = ·060 = 1		Al_2O_3 = ·089 = 1		Ab.	= 47·3
SiO_2 = ·360 = 6		SiO_2 = ·534 = 6		Qtz.	= 13·2
MgO = ·014 = 1	Pyroxene	FeO = ·012 = 1	Magnetite	Pyr.	= 3·1
CaO = ·014 = 1		Fe_2O_3 = ·012 = 1		Magn.	= 2·5
SiO_2 = ·028 = 2					
		SiO_2 = ·217 = free Quartz			100.0

The only deviation here is some 0·14 per cent of lime, which belongs in the minute amount of apatite and titanite present and of which no account has been taken. The rock is thus

shown to consist of over 80 per cent of alkaline feldspar of varying mixtures, but whose average composition would be nearly Or_1Ab_7.

It therefore stands on the boundary in the alkali series between the granites and quartz syenites; it might be termed an augite aplite or granite or a quartz syenite. It is a noticeable fact how high a silica content purely feldspathic rocks may carry (albite with $SiO_2 = 68{\cdot}7\%$) and in this case high silica may still yield little free quartz.

Basic syenite or monzonite (*Yogoite*).—This variety constitutes the main mass of the stock. It seldom occurs in prominent exposures, but forms talus slopes whose luxuriant covering of grass conceals the angular debris blocks into which the rock breaks. This type occurs in different parts of the mass, showing identical characters. The specimen described comes from the base of the slopes east of Beaver Creek.

The rock is of a medium gray color, is evenly and moderately fine granular, the average size of grain being about 1^{mm} in diameter. It is easily seen to be composed of a white feldspathic component mixed with about equal quantities of a dark augite and biotite, the augite dominating the biotite in amount. They do not appear porphyritic in development but in grains like the feldspar; more rarely the biotite is seen in somewhat larger, ragged, poikilitic plates.

In thin section the rock is found to be composed of the following minerals: *Iron ore*, *apatite*, *diopside*, *biotite*, soda-lime feldspar varying from *labradorite* to *oligoclase*, and *orthoclase*.

The *diopside* is a pale green, and is apt to occur in short, stout prisms which have rough, rounded exteriors giving the mineral an anhedral habit.

The *biotite* is also allotriomorphic with respect to the other minerals; it has a strong pleochroism between very pale yellow and deep olive brown. Its period of formation overlaps the pyroxene but commenced later; it is very common to find the pyroxenes with an interior zone filled with biotite shreds; within this it does not occur, and this marks the commencement of the biotite crystallization. The biotite frequently surrounds grains of iron ore.

The *plagioclase* feldspar occurs in short, thick laths which are very small in size compared with the other components, and are generally quite idiomorphic. In amount it is much less than any of the other components. The small laths lie scattered around among the other components, and are enclosed in the orthoclase without orientation. It shows carlsbad, albite, and rarely pericline twinning. In composition it is somewhat variable, the interior parts being as usual more basic; the interior part is labradorite, and the outer portion varies through

andesine to oligoclase. Sometimes the crystals are not zonal and these may be of labradorite. Thus a section in the zone 001 on 100 perpendicular to 010 gives for the albite twins in one carlsbad half 35°, 35°, in the other half 17° and 19°, then $\delta = 17°$, and the feldspar is a labradorite between Ab_1An_1 and Ab_3An_4. The index of refraction is also higher than the orthoclase, in which the laths lie. Its period of formation laps that of the biotite.

The *orthoclase*, which was the last mineral to crystallize, fills the interspaces and encloses the other components in a poikilitic manner over considerable areas. Its determination as orthoclase rests on the fact that in numerous sections perpendicular to an obtuse positive bisectrix the angle of extinction varied from 5 to 7 degrees from the trace of the cleavage 001 in the obtuse angle β, the section being oriented by this cleavage and by inclusions which give the direction of the vertical axis as well as a parting which appears to be parallel to the prismatic faces. Thus in such a section the angle was measured 63 and $\beta = 63° 54'$. The extinction measured with the Bertrand ocular is 7° 30′ from the trace of the good cleavage 001 in the obtuse angle. The albite molecule is surely present in it to a certain extent, and some examples contain patches of interlaminated albite.

All of the minerals are very fresh, and the structure is hypidiomorphic, typical of granular abyssal rocks. The differences in the mineral composition of this rock and the syenite just described are of the same kind as those noted between the two types described from Yogo Peak, but the contrast is even greater, as will be apparent from the chemical analysis.

An analysis of this type, made in the laboratory of the U. S. Geological Survey by Dr. H. N. Stokes, is given in the first column of the table on the next page.

Not knowing the exact proportions in which the elements enter into the various minerals present, it is not possible to calculate their relative percentages, but it is clear that the albite molecule must be largely present in the alkali feldspars.

It will be seen that the agreement between this type and the one from Yogo Peak is very satisfactory, as shown by the small differences of only about 1 per cent in SiO_2, Al_2O_3, and MgO. The mineral composition and structure are also the same.

Since our paper on Yogo Peak was published the first half of the new edition of Rosenbusch's "Mikroskopische Physiographie" has come into our hands, and almost simultaneously a notable work by Brögger chiefly on the rocks of Predazzo in Tyrol. The latter shows that the granular rocks there exposed form a transition group between the alkali feldspar and plagioclase groups with all grades from those rich in feldspar to those free

from it; further, the author proposes to erect a new series co-equal with the granite-syenite and diorite-gabbro series; the middle members of this series are the "monzonites" and in minerals, structure, and chemical composition they are the equivalents of our Yogoites.

	I.	II.	III.	Ia.
SiO_2	52·81	54·42	54·20	·8801
Al_2O_3	15·66	14·28	15·73	·1520
Fe_2O_3	3·06	3·32	3·67	·0191
FeO	4·76	4·13	5·40	·0661
MgO	4·99	6·12	3·40	·1247
CaO	7·57	7·72	8·50	·1352
Na_2O	3·60	3·44	3·07	·0580
K_2O	4·84	4·22	4·42	·0513
$H_2O+110°$	·93	·38	·50	
$H_2O-110°$	·16	·22		
TiO_2	·71	·80	·40	
Fl	trace	----	----	
Cl	·07	----	----	
P_2O_5	·75	·59	·50	
SO_3	trace	----	----	
MnO	trace	·10	·70	
BaO	·24	·32	?	
SrO	·09	·13	?	
Li_2O	trace	trace	----	
	100·24	100·19	100·49	
$O=Cl$	·02			
	100·22			

I. Monzonite, "Yogoite," or basic syenite, Beaver Creek, Bearpaw Mountains. H. N. Stokes anal.

II. Monzonite, "Yogoite," or basic syenite, Yogo Peak, Little Belt Mountains, Montana. W. F. Hillebrand anal.

III. Monzonite (Brögger, Erupt. Gest. Predazzo, 1895, p. 24). V. Schmelck anal.

Ia. Molecular proportions in No. I.

This is also clearly shown by analysis No. III, which is that of a typical monzonite. Rosenbusch,* however, regards these as being representatives of the basic syenites, or that member of the syenite family rich in the dark-colored components as its distinguishing characteristic. He calls it the monzoni type.

As this type of granular rock corresponds so closely in all essential features and in chemical composition with our yogoite and the name "monzonite" has priority in date, we desire to

* Mikr. Phys. Mass. Gest., 3d ed., p. 123, 1895.

withdraw the term "yogoite" and substitute "monzonite" in its place and thus avoid confusion in the nomenclature.

In connection with the associated occurrence of this monzonite and the alkali syenite previously described, it is of interest to recall the keen remark of Rosenbusch* on the probable presence of an alkaline syenite at Monzoni.

Leaving aside then for the present Brögger's radical proposal for the new group, the augite syenite family, taking into consideration the relative quantities of light and dark minerals according to our method of classification† would be as follows: *sanidinite*, *augite syenite* (åkerite and laurvikite types), *monzonite*, *shonkinite*, *pyroxenite*. This leaves out of consideration the plagioclase in the monzonite; if it is considered and Brögger's monzonite group be adopted, a gap is left to be filled by some type of hitherto undescribed alkaline syenite, rich in augite and free from plagioclase.

Gradational types between the monzonite and the more basic shonkinite were collected and their occurrence is quite what we should expect.

Shonkinite type.—The shonkinite type, the complementary rock of the acidic syenite, occurs in the outer or peripheral part of the stock. This rock crumbles readily in weathering, and good exposures do not occur. Pyritic impregnations have, however, led mining prospectors to drift into the rock, and the tunnel face and dump heaps afford quite fresh unaltered material. At the Zortman claim the rock is mottled and streaked with feldspathic material often in stringers and slender extended portions (*Schlieren*), and large irregular feldspar crystals occur. The normal rock is, however, free from these streakings, the specimen analyzed being entirely devoid of such material.

It is a very dark, basic-looking rock of a moderately coarse grain and strongly micaceous appearance from the light reflected from innumerable cleavages of biotite. In the description which follows, the type from the Bearpaw mine referred to in the first part of this paper is included, as it differs in no essential from the present occurrence.

Under the microscope it is found to consist essentially of the same minerals as the monzonite previously described, though in different proportions; they are *apatite*, *iron ore*, *diopside*, *biotite*, *alkali feldspar*, and in addition a very little *olivine* and probably a little *nephelite*.

The *apatite* is present in short, stout crystals which are clear and colorless. The *diopside* is present in rather long, slender prisms and in short, round anhedral grains; it is of a very clear

* Mikr. Phys. Mass. Gest., 3d ed., p. 124, 1895.

† See this Jour., Rocks of Yogo Peak, p. 478, vol. l, 1895.

pale green, of a wide extinction angle, good cleavage, and contains a few inclusions of glass, biotite, and iron ore.

The *biotite* is of a brown, strongly pleochroic variety, which passes at times into a green one. It has the character of a granitic biotite and is not very idiomorphic. Although so prominent megascopically, it is less in amount than the pyroxene. It frequently encloses iron ore and patches of iron ore and biotite are found which are evidently recrystallizations after a former olivine. In a few cases a little olivine remainder has been found in them. These are not like the opacite resorptions found in effusive rocks, but composed of rather coarse groupings of the minerals.

The *feldspar* is found in broad masses which yield wide plates in the section. Only in one specimen was the feldspar developed in thin, flat tables on *b* (010) with irregular boundaries. The broad fields of it enclose all the other minerals in a poikilitic manner. In its composition it is wholly anorthoclase or soda-orthoclase. This is shown by the fact that sections perpendicular to an obtuse ($2H > 115°$) positive bisectrix give extinction angles in a positive sense of 9° for the Bearpaw mine type and 12° 30′ for the Beaver Creek occurrence from the trace of the cleavage *c* (001). The orientation of the section is given by this cleavage, and the direction of the vertical axis *c* by lines of altered inclusions and by a parting which appears to be parallel to a prism face; between these the angle β was measured 63° in each case.

The feldspar, moreover, presents all the characteristics of the soda-orthoclase group, which have been so frequently mentioned in these papers and shown to be dominant in the Bearpaw rocks. It has the homogeneous appearance with low powers, and the patchy varying appearance with high ones between crossed nicols. In one or two instances plates have shown an extremely fine, delicate, scarcely perceptible twinning following the albite law. The feldspar is indeed similar to the cryptoperthite of the Norwegian alkali rocks.

No trace of any lime-soda feldspar has been found in these shonkinites. It did not occur in the original type at Square Butte and was very sparingly present in the Yogo Peak variety, a noteworthy fact when the high per cent of lime is considered. The presence of a little *nephelite* is suspected as the rock powder yields a little gelatinous silica (not due to the olivine) on treatment with very dilute acid. We have not found it in the sections and only a mere trace can be present.

The structure is the typical hypidiomorphic one characteristic of even-grained abyssal rocks.

The chemical composition of the Beaver Creek type is shown in the following analysis made for us by Dr. H. N. Stokes:

	I.	II.	III.	IV.	Ia.
SiO_2	50·00	48·98	46·73	50·43	·8333
Al_2O_3	9·87	12·29	10·05	10·21	·0958
Fe_2O_3	3·46	2·88	3·53	11·57	·0216
FeO	5·01	5·77	8·20		·0696
MgO	11·92	9·19	9·68	5·58	·2980
CaO	8·31	9·65	13·22	14·82	·1484
Na_2O	2·41	2·22	1·81	1·48	·0388
K_2O	5·02	4·96	3·76	3·70	·0532
TiO_2	·73	1·44	·78	?	
$H_2O-110°$	·17	·26	·78	·87	
$H_2O+110°$	1·16	·56			
Cr_2O_3	·11	trace	----	----	
MnO	trace	·08	·28	----	
NiO	·07	----	----	----	
BaO	·32	·43	undet.	?	
SrO	·07	·08	undet.	?	
Fl	·16	·22	----	----	
$CaCO_3$	----	----	----	·52	
Cl	·08	----	·18	----	
P_2O_5	·81	·98	1·51	·70	
SO_3	·02	----	trace	----	
CO_2	·31	----	----	----	
Li_2O	trace	trace	trace	----	
	100·01	99.99	100·97	99.88	
O=Cl & Fl	·08	·08	·04		
	99·93	99·91	100·93		

I. Shonkinite, Beaver Creek, Bearpaw Mountains, H. N. Stokes anal.

II. Shonkinite, Yogo Peak, Little Belt Mountains, Montana. W. F. Hillebrand anal.

III. Shonkinite, Square Butte, Highwood Mountains, Montana, L. V. Pirsson anal.

IV. Shonkinite, Monzoni (Lemberg, Zeitschr. d. deutsch. G. G., 1872, p. 201), Lemberg anal.

Ia. Molecular proportions in No. I.

It will be seen in the above that the rock has all the characters of the type, high lime, iron, and magnesia and also high alkalies with potash dominating the soda. We have introduced the analyses of the previous types described by us and also one of a pyroxene-orthoclase rock from Monzoni, being indebted to Brögger* for the reference. It should evidently fall under this type.

Brögger† remarks that shonkinite is "a peculiar pyroxenite rich in plagioclase"; this is certainly true, but the same

* Eruptionsfolge eruptivgesteine Predazzo, 1895, p. 66.

† Loc. cit.

definition would apply as well to augite-syenite, or gabbro could be called a peridotite rich in plagioclase. A pyroxenite, according to our conception, is essentially a *non-feldspathic* rock, and we desire to emphasize at this point that in the shonkinites described by us the alkali feldspars are a constant and essential component, true pyroxenites, the practically non-feldspathic member of the series, never having been observed at any of the localities.

As a matter of fact, if the syenites be estimated as a series practically free from plagioclase and we adopt Brögger's monzonite group as an alkali-feldspar-plagioclase series as he defines it, then the shonkinites are the syenite equivalents of the olivine monzonites, while the pyroxenites—the end terms—are alike in each, the two series approaching as the feldspars diminish until they unite in the last term, the pyroxenites.

This makes the fourth occurrence of this rock type described by us from widely separated and distinct localities in central Montana. We have material, also, from others which we hope to describe at a future date. It is of interest to note that theralite (a plagioclase-nephelite, granular rock) which shonkinite strongly resembles in the character and abundance of the ferro-magnesian minerals, also occurs in this region, in the Crazy Mts., but appears to be a very rare type, the shonkinite being a more common and dominating one.*

Differentiation at the Beaver Creek core.—To enter into detail concerning the facts of the differentiation of igneous magmas at the Beaver Creek core and their bearing on theoretic petrology, would be merely a repetition of the discussion given in our former papers. We have thought it best, therefore, to merely present the analyses (p. 362) in comparison with those at Yogo Peak and let the figures tell their own story. The lower figure in the case of each oxide refers to the Beaver Creek, the upper one to the Yogo Peak series.

At Yogo Peak the series began with a quartz-syenite porphyry,† and next to it came the syenite. The contact, if any, between them is covered, and we cannot tell whether the quartz-syenite porphyry is a differentiation in place, as seems

* While this article was passing through the press we received a paper on "Malignite, a family of basic plutonic orthoclase rocks rich in alkalies and lime," by Prof. A. C. Lawson (Bull. Univ. California, vol. i, pp. 337–362, March, 1896). These rocks appear closely related chemically and in part mineralogically to the theralites and shonkinites, and although the author does not appear to recognize it they clearly belong in Rosenbusch's theralitic magma series (Mass. Gesteine, 3d ed., p. 385, 1895).

† The analysis of the quartz-syenite porphyry given is not that of the rock occurring at Yogo Peak but of a precisely similar type from Big Baldy Mountain, a few miles distant. It represents perfectly, however, the Yogo Peak differentiation.

most probable, or a later intrusion. In any case it is a differentiated phase of the same magma. As seen in the table below, its correspondent exists at Beaver Creek, but the one corresponding to the syenite is wanting. It probably exists, but was not observed in the hasty examination we have been able to make.

	Quartz Syenite.	Syenite.	Monzonite "Yogoite."	Shonkinite.
SiO	67·04	61·15	54·42	48·49
	68·23	----	52·81	50·00
Al_2O_3	15·25	15·07	14·28	12·29
	15·12	----	15·66	9·87
Fe_2O_3	1·69	2·03	3·32	2·88
	1·90	----	3·06	3·46
FeO	1·13	2·25	4·13	5·77
	·84	----	4·76	5·01
MgO	1·75	3·67	6·12	9·91
	·54	----	4·99	11·92
CaO	2·17	4·61	7·72	9·65
	·92	----	7·57	8·31
Na_2O	4·09	4·35	3·44	2·22
	5·30	----	3·60	2·41
K_2O	5·10	4·50	4·22	4·96
	5·57	----	4·84	5·02

The other types are clearly shown. In general a comparison of the two localities shows the Beaver core as the more alkaline of the two; and the most important difference is that at Beaver Creek; the Al_2O_3 and MgO show a much greater degree of concentration and inverse variation than at Yogo. This inverse variation is especially marked in the Beaver Creek monzonite and shonkinite, which otherwise do not greatly differ from one another. They thus furnish a most instructive example of the fact that a nearly similar silica percentage may exist in two types of rocks which differ greatly in appearance, one with high Al_2O_3 being clearly feldspathic and recalling many medium diorites in appearance, while the other, with high MgO, is dark, basic-looking, and with evidently preponderant ferromagnesian minerals.

There are a number of interesting dike rocks connected with the Beaver stock; these have been studied, and an account of them, together with some other occurrences of rare types of both intrusive and extrusive rocks in the Bearpaw Mts., will be shortly published in a second paper in this Journal.

Washington and New Haven, March, 1896.

Art. XLII.—*Röntgen Rays not Present in Sunlight;* by M. Carey Lea.

If Prof. Röntgen's views as to the nature of the X-rays are correct, it would seem that they ought to be found amongst the many forms of radiant energy received from the sun, and various observers have thought that they so found them. Some experiments, the most important of which will be here briefly stated, do not seem to support this opinion.

1. A very sensitive dry plate (S. 27) was placed between the leaves of a book so that 100 leaves and the red paper cover should be between the sensitive film and the sunlight. The book was then packed in a box frame to exclude all light from the sides. A large and thick lead star was then fastened on the outside of the book and the arrangement was exposed to exceptionally bright sunshine from 11 A. M. to sunset, March 7. The plate when put into a developing bath behaved as if unexposed. A prolonged development did not bring out a trace of an image of the lead star.

It will be remembered that Prof. Röntgen found that the X-rays penetrated easily through a book of 1000 printed pages. Indeed G. Moreau has recently stated that in his hands the X-rays had penetrated through "several meters" of cardboard.* So that the above experiment seems to be very significant.

2. A piece of sheet aluminium $1{\cdot}2^{mm}$ thick was accurately fitted into a frame. A very sensitive plate was placed behind it and a lead star in front. With three hours' exposure not a trace of an image could be obtained. This experiment was varied by substituting thin aluminium foil for the plate, also by using bromide paper as the sensitive surface. No images in any case were obtained.

3. The sun's rays or some portion of its radiation passes readily through wood, if the latter is not too thick. Thus through a piece of white pine $\frac{3}{16}$ of an inch thick, images that could readily be developed were obtained by three minutes exposure to afternoon sunlight. With half an hour's exposure the images were brilliant.

A panel about 12 inches square was removed from an inside shutter and replaced with a piece of white pine $\frac{1}{4}$ inch thick. When the room was thoroughly darkened, reddish light could be seen to pass through the board. So that wood of this thickness is plainly translucent to the sight.

The sun's light may be examined for X-rays also by fluorescence.

*C. R., cxxii, p. 238: quoted Chem. News, Feb. 21, 1896, p. 85, (No. 1891.)

4. The panel just described was replaced by one of stout book board. With the sun shining on this book board directly and not through glass, paper marked with a saturated solution of barium platinocyanide exhibited no indications of fluorescence when placed behind the board.

5. Three thicknesses of Bristol board were pasted together, a circle was cut out, to one side of which barium platinocyanide was applied. The circle was then placed in a pasteboard tube, (an arrangement, I believe, proposed by Prof. Magie.) When the sun was looked at through this tube the barium salt exhibited fluorescence. But the interposition between the card and the sun of very thin aluminium foil sufficed to cut off the fluorescence.

These concurrent results seem to indicate the absence of X-rays from sunlight.

Charles Henry* quotes an opinion of H. Poincaré that all bodies whose phosphorescence is sufficiently intense, emit in addition to luminous rays the X-rays of Röntgen, whatever may be the cause of their fluorescence. Henry quotes confirmatory experiments of his own made with zinc sulphide.

It seemed worth while to ascertain if this principle is of general application. A dilute solution of uranin was exposed to sunlight, using a large surface of solution so as to get the best effect. A short distance over the surface was placed a sensitive film protected by aluminium foil $\frac{1}{10}$ of a millimeter in thickness and with a lead star interposed. Two hours exposure gave no result. The experiment was repeated with acid solution of quinine, with which five hours exposure gave no result.

I have also examined the Welsbach light for X-rays. This light is usually burned under a chimney which increases the brightness but interposes glass between the source of light and the sensitive film. Even without a chimney the light is bright. The experiment was therefore made both ways. No X-rays could be detected. Nothing capable of passing through aluminium foil $\frac{1}{10}$ of a millimeter in thickness by five hours exposure to the uncovered flame.

*C. R. cxxii, 312; Chem. News, Feb. 28, 1896, p. 98.

Art. XLIII.—*The Potomac River Section of the Middle Atlantic Coast Eocene;* by Wm. Bullock Clark.

Our knowledge of the Tertiary geology and paleontology of the middle Atlantic slope has been largely increased since the days of Conrad and Rogers, yet few fields afford better opportunities for continued observation, and in none is there greater need of a careful revision of results. Very divergent opinions have prevailed and to-day find expression in the different interpretations of the data.

General Features of the Formation.

The Eocene strata of the middle Atlantic slope, described by Darton* under the name of the *Pamunkey Formation*, form a belt of varying width extending from northeast to southwest somewhat to the west of the center of the coastal plain. This belt has been traced almost continuously from the southern portion of Newcastle County, Delaware, to the valley of the Nottaway river in southern Virginia, and although at times buried beneath later deposits it presents fine exposures along all the leading stream channels, while not infrequently broad expanses of the formation outcrop at the surface in the intervening country.

Lithologic Characters.—The deposits are typically glauconitic and are found in their unweathered state either as dark gray or green sands or clays. The glauconite varies in amount all the way from very nearly pure beds of that substance to deposits in which the arenaceous and argillaceous elements predominate, although the strata are generally very homogeneous for considerable thicknesses. At some horizons the shells of organisms are found commingled with the glauconitic materials in such numbers as largely to make up the beds, producing what is known as a green-sand marl. These beds are at times indurated, forming true limestone bands. This latter phase is seen typically developed both at Fort Washington, Maryland, and Aquia Creek, Virginia, interstratified with the unconsolidated green-sand layers.

When the glauconite is weathered the deposits lose their characteristic gray or green color, and generally become lighter gray with reddish or reddish-brown streaks or bands, or may become entirely of the latter color. In this condition they are often cemented into a ferruginous sandstone. This change

* Bull. Geol. Soc. Amer., vol. ii, p. 411, 1891.

particularly characterizes the Eocene deposits of Delaware and the eastern shore of Maryland as well as of Anne Arundel County on the western side of the Chesapeake. A very coarse phase of the consolidated sand-rock is seen at Mt. Misery on the Severn river.

In the less completely weathered portions of the formation the change is shown in the mottled yellow and brown character of the more superficial beds, the glauconitic grains still showing their green color when crushed. Thin iron crusts at times appear under these conditions. When the glauconite is largely or more rarely entirely absent, the deposits consist of black or grey sands or clays, the latter at times micaceous and in a few instances carbonaceous.

A pebble bed has been found at some localities at the base of the formation.

Strike, Dip and Thickness.—The strike of the Eocene deposits in Delaware and Maryland is approximately N.E. to S.W. while in Virginia the prevailing trend is more nearly N. to S. This change in the direction of strike is attained in the area between the Patuxent and Rappahannock rivers, chiefly in the Potomac basin.

The dip of the strata differs in the various portions of the area, as shown by section-lines and well-borings, from 10 to 20 feet to the mile, but along the Potomac river section, where detailed measurements were made by the writer, it is on an average about 12½ feet to the mile.

The results obtained from a study of the various section-lines and well-borings show that the average thickness of the deposits is somewhere in the vicinity of 200 feet, although estimates based upon the Potomac river section as well as upon well borings in the area to the east of Fredericksburg show that it reaches quite 300 feet in that portion of the middle Atlantic slope.

Potomac River Section.

The most extensive section of the Eocene in the middle Atlantic slope is found in the valley of the Potomac river, a nearly complete sequence of the several members of the formation being exhibited in the bluffs between Aquia Creek, Stafford County, Virginia and Pope's Creek, Charles County, Maryland.

Detailed stratigraphy.—The accompanying columnar section shows the relative thickness and character of the deposits in this area. The several members of the formation are numbered in ascending order. The full thickness is about 300 feet.

No. 1. The thickness of the Eocene beneath the basal strata of the Aquia Creek bluff, cannot fall far short of 60 feet. Some exposures are seen in the ravines to the west of the bluff, but no complete sequence of the beds has been found. The almost entire absence of fossils renders it impossible to say anything regarding the faunal relations of the strata. The deposits are typical green-sands, at times somewhat argillaceous and with a basal pebble-bed overlying the Cretaceous at several points.

No. 2. This bed is composed of dark unconsolidated green-sand packed chiefly with the shells of *Crassatella alæformis*, *Dosiniopsis lenticularis* and *Cytherea ovata*. The bed is about 12 feet in thickness at the upper end of the Aquia Creek bluff, but gradually declines in elevation until it passes below water level about half way to Marlborough Pt. The same bed appears at water level on the opposite side of the Potomac river at Clifton Beach.

No. 3. The green-sand marl composing this bed is generally indurated so as to form a firm band, 2 to 3 feet in thickness. The limestone is highly glauconitic and of dark color, and is filled with the shells, or more commonly the casts of the same species as the previous bed, together with *Ostrea compressirostra* and here and there a specimen of *Turritella mortoni*.

No. 4. This bed is a typical unconsolidated green-sand containing large numbers of the same forms as No. 3. It reaches about eight feet in thickness.

No. 5. This limestone bed is very persistent, and forms a conspicuous ledge along the face of the Aquia Creek bluff until it passes below tide level near its eastern extremity. It is commonly about two feet in thickness and is packed with fossils among which the forms mentioned below are conspicuous, in addition to the species already mentioned as characteristic for zones 2 to 5 which still remain the most common types, viz: *Pholadomya marylandica*, *Panopæa elongata*, *Tellina virginiana*, *Pholas* (?) *petrosa*, *Fusus* sp., *Caricella* sp., etc.

No. 6. The dark characteristic green-sand overlying the limestone ledge is packed with the

common species of the previous zones. In the main portion of the Aquia Creek bluff this bed is only one foot in thickness, but thickens to the eastward, and just above Marlborough Pt. contains among other forms several species of corals, including *Eupsammia elaborata*, *Turbinolia acuticostata*, and *Paracyathus* (?) *clarkeanus*.

No. 7. Overlying the preceding bed, and really a continuation of it, is a zone in which the fossils are few in number and much broken. This bed is about seven feet in thickness.

No. 8. The highly characteristic green-sands and green-sand marls of the previous zones are succeeded by a bed some thirty feet in thickness, in which the glauconitic grains have been extensively weathered, giving the strata a greenish-grey appearance which changes to a reddish-brown in the upper layers. Several irregular bands packed with *Turritella mortoni* are present both in the Aquia Creek and Potomac Creek sections, while associated with that species at both localities are *Turritella humerosa*, *Cucullæa gigantea*, *Crassatella alæformis*, *Ostrea compressirostra* and other forms. The upper portions of this bed have afforded most of the species from the Potomac Creek bluff. This zone forms the base of that bluff, while it is more than thirty feet above water level in the Aquia Creek section three miles above.

No. 9. The thick-bedded limestone layers which compose this zone are almost exclusively made up of the shells of *Turritella mortoni*, forming a true Turritella rock. Between the indurated bands are layers of unconsolidated and much-weathered green-sand which contain very few fossils of any description. Great masses of this Turritella rock strew the shore at the base of both the Aquia Creek and Potomac Creek bluffs. The bed is about ten feet in thickness in the Aquia Creek bluff, but reaches fourteen feet in places in the Potomac Creek section.

No. 10. The greenish-grey sand overlying the Turritella bed is more argillaceous than the underlying beds of the Eocene. The glauconite grains have been much weathered and nearly all trace of the shell substance removed from the few forms recognized. The casts found at the Potomac Creek bluff are chiefly those of a *Cytherea*. No fossils were found at the Aquia Creek bluff. The bed is about twenty-five feet in thickness.

No. 11. A thin highly indurated layer of argillaceous green-sand overlies No. 10 in the Potomac Creek bluff, and among several indeterminable casts a few specimens of *Venericardia planicosta* were found.

No. 12. This bed of greenish-grey argillaceous sand still shows some unweathered grains of glauconite, but is devoid of fossils so far as observed. It reaches eight feet in thickness.

No. 13. This bed consists of a light grey glauconitic sand somewhat weathered and filled with shells of *Venericardia planicosta*. It reaches three feet in thickness. This zone is very persistent and has been found outcropping in several of the ravines to the east and south of Potomac Creek, as well as in the bluff upon the river front.

No. 14. Overlying the Venericardia layer is a bed of greenish-grey argillaceous sand some four feet in thickness, which contains a great number of bands filled with gypsum crystals. No fossils were observed.

No. 15. This bed consists of greenish-grey argillaceous sand in which the glauconite grains have been extensively weathered. No fossils were found. The bed has a thickness of twenty-five feet.

No. 16. In this zone have been placed the green-sand strata intervening between the upper layers of the Eocene in the Potomac Creek section and the base of the Woodstock section.

Comparatively little is known regarding this portion of the series, as no satisfactory outcrops appear on the river bluffs, although the strata are found in an unfossiliferous condition in some of the ravines to the west of the Woodstock area. The estimated thickness of these beds is fifty feet.

No. 17. The highly glauconitic beds at Woodstock, Virginia and Pope's Creek, Maryland are grouped together in one zone, as no satisfactory separation could be made. The deposits are very homogeneous, although an inconstant indurated layer appears about six feet above the base of the Woodstock section with a band of *Venericardia planicosta* below it, while a thin bed of *Ostrea sellæformis* also occurs in the lower part of the zone, although evidently not always at the same horizon. Otherwise the fossils are the same throughout, so far as observed. The most common forms are *Protocardia virginiana*, *Cytherea subimpressa*, *Corbula nasuta*, *Corbula oniscus*, *Ostrea sellæformis*, *Pectunculus idoneus*, *Leda improcera*, *Leda parva*, *Nucula magnifica*, *Lucina dartoni*, *Lucina uhleri*, *Lucina whitei*, *Ringicula dalli* and *Cylichna venusta*.

Paleontological characteristics.—The paleontological characteristics of the several zones indicate two very distinct faunal stages in the middle Atlantic slope Eocene, the first typically developed in zones 2 to 9, and the second in zone 17. The characteristics of zone 1 and of zones 10 to 16 cannot be readily made out in the Potomac River area on account of the extensive weathering of the beds, although in some of the adjoining districts there is an intermingling of some of the forms of the two stages in the beds intervening between 9 and 17. To the two faunal divisions, the names of *Aquia Creek Stage* and *Woodstock Stage* have been already given by the writer.*

* Johns Hopkins Univ. Circulars, vol. xv, p. 3, 1895.

Aquia Creek Stage.—The most common species of the Aquia Creek stage are *Turritella mortoni* confined chiefly to zones 8 and 9, *Cytherea ovata* and *Crassatella alæformis* confined largely to zones 2 to 7, *Cucullæa gigantea* mainly found in zone 8, *Ostrea compressirostra** most common in zones 6 and 7, and *Dosiniopsis lenticularis*, for the most part limited to zones 2 to 5. Other species found in this stage are *Thecachampsa marylandica*, *Trionyx virginiana*, *Ischyrhiza* (?) *radiata*, *Myliobatis copeanus*, *Carcharodon polygurus*, *Lamna* (?) *obliqua*, *Oxyrhina hastalis*, *Odontaspis elegans*, *Galeocerdo contortus*, *Nautilus* sp., *Tornatella bella*, *Pleurotoma harrisi*, *Volutilithes* (*Athleta*) *tuomeyi*, *Volutilithes* sp., *Caricella* sp. *Mitra marylandica*, *Pyropsis* sp., *Fusus* (*Levifusus*) *trabeatus*, *Fusus* (*Strepsidura*) *perlatus*, *Fusus* sp., *Fulgur argutus*, *Lunatia marylandica*, *Natica cliftonensis*, *Turritella humerosa*, *Calyptræa trochiformis*, *Vermetus* sp., *Scala virginiana*, *Gibbula glandula*, *Solarium* sp., *Gastrochæna* sp., *Pholas* (?) *petrosa*, *Coralliophaga bryani*, *Tellina williamsi*, *Panopæa elongata*, *Pholadomya marylandica*, *Lucina aquiana*, *Venericardia planicosta*, *Crassatella aquiana*, *Leda protexta*, *Modiola potomacensis*, *Pecten johnsoni*, *Pecten* sp., *Ostrea* sp., *Serpula* sp., *Paracyathus* (?) *clarkeanus*, *Turbinolia acuticostata*, *Eupsammia elaborata*, besides many species of Foraminifera.

Woodstock stage.—The Woodstock stage is characterized by the following common species, viz: *Protocardia virginiana*, *Cytherea subimpressa*, *Corbula nasuta*, *Corbula oniscus*, *Ostrea sellæformis*, *Pectunculus idoneus*, *Leda improcera*, *Leda parva*, *Nucula magnifica*, *Lucina dartoni*, *Lucina uhleri*, *Lucina whitei*, *Venericardia planicosta*, *Ringicula dalli* and *Cylichna venusta*. Among other species found at this horizon may be mentioned *Carcharodon polygurus*, *Lamna* (?) *obliqua*, *Oxyrhina hastalis*, *Odontaspis elegans*, *Galeocerdo contortus*, *Cythere* sp. *Mangilia* (*Pleurotomella*) *bellistriata*, *Fusus* (*Levifusus*) *trabeatus*, *Lunatia marylandica*, *Cadulus bellulus*, *Teredo virginiana*, *Solemya petricoloides*, *Corbula aldrichi*, *Tellina virginiana*, *Cytherea ovata*, *Diplodonta hopkinsiensis*, *Yoldia cultelliformis*, *Modiola potomacensis*, *Pecten rogersi*, together with numerous species of Foraminifera.

Correlation of the Deposits. — By common consent the diversified and extensive Eocene deposits of the Gulf area have come to be regarded as the type for the eastern border region and the various Eocene deposits of the Atlantic coast states have been assigned to a position in this series, although very different limits have been given by the different authorities. The Eocene deposits of the middle Atlantic slope have

* Several immature oysters found at this horizon bear a strong resemblance to the young of *Ostrea sellæformis*.

been regarded by some to represent a single minor division of the Gulf section, while others have regarded them as an equivalent of a larger portion of that series. The latter conclusion seems to the writer, after a consideration of both the geological and paleontological data, to be the only tenable position. In the past too little attention has been given to the geological phenomena, while, at the same time, the knowledge of the fossils has been wholly insufficient for a proper interpretation of the faunal characteristics of the formation.

The Geological Criteria.—The lithological and stratigraphical characteristics of the Eocene in the middle Atlantic slope afford some important criteria for the correlation of the strata. To begin with, the homogeneous nature of the deposits is a characteristic feature, indicating conditions throughout the period of Eocene deposition, undisturbed by important physical changes. Again, the fact that the strata are so largely made up of secondary materials shows that the position of accumulation was in the vicinity of a coast reached by no large rivers bearing sediment, while at the same time sufficiently removed from the coast line to be unaffected by shore conditions. It is further evident that these deposits, which are so largely glauconitic, were accumulated with exceeding slowness, as has been shown in the case of the formation of greensands upon the beds of existing seas.

Now when we compare these conditions of accumulation in the middle Atlantic slope with the conditions that prevailed in the Gulf region, marked differences appear. In the latter area numerous rivers, draining the interior of the continent, discharged great quantities of material throughout much of Eocene time, making the deposits highly diversified. Instead of the green-sands and greenish and black clays of the middle Atlantic slope, which no longer to any large extent characterize the strata, are found coarser beds of sand and clay, often partly calcareous, which give every indication of more rapid accumulation. To compare, therefore, the 200 feet and more of green sands and clays of the middle Atlantic slope with one or two subdivisions of hardly equal thickness in the Gulf region would, even upon stratigraphical grounds without the aid of fossils, hardly be attempted. The strata of the Middle Atlantic slope must be represented in the Gulf by deposits many times their thickness.

The general relations of the strata, occurring as they do between the Cretaceous and Neocene along both the Atlantic and Gulf coasts, give some indications of the continental movements to which each province was subjected. Although the movements may not have been absolutely contemporaneous they afford nevertheless satisfactory criteria for the broad correlation of the deposits, their more exact parallelism being determined upon other grounds.

Paleontological Criteria.—Although life-zones are frequently of great extent and may be accepted as the most trustworthy evidence of geological contemporaniety, yet the subdivisions of a fauna recognized in one area under one set of physical conditions may not be found in another area, distant from the first, where the conditions are wholly different. It is scarcely to be expected that the vertical range of the species will be the same in the two regions, while the time occupied in migration is a factor that cannot be ignored in most classes of organisms. Forms, likewise, which, from their persistence under one set of physical conditions, may be regarded as typical, are often entirely wanting in an adjacent province. The presence also of a large number of new species is of itself evidence of change in physical surroundings, and renders it necessary to proceed with great caution when detailed correlations of the strata are attempted. Especially is this true when the areas are widely separated in latitude so that temperature differences occur.

When we come now to compare the faunal charactistics of the Eocene of the middle Atlantic slope with those of the Gulf we find first of all that the assemblage of forms is very different in the two areas. The great majority of the species is unlike, while the identical forms are mainly of wide vertical range. Most of those regarded as the same also show certain differences, as the result of the dissimilar conditions under which they lived, so that the determination of the middle Atlantic coast forms often involves certain doubts as to their identity with Gulf species. The sequence of forms is likewise different, a differentiation into the great number of subdivisions recognized in the Gulf, not occurring in Maryland and Virginia.

The Aquia Creek fauna which is typically developed in zones 2 to 9 in the Potomac area occupies, so far as can be with certainty determined, only about 70 feet of strata some 60 feet from the base of the formation and contains among other Gulf species *Turritella mortoni*, *T. humerosa*, *Tornatella bella* *Volutilithes* (*Athleta*) *tuomeyi*, *Fusus* (*Strepsidura*) *perlatus*, *Dosiniopsis lenticularis*, *Venericardia planicosta*, *Cucullæa gigantea*, and *Ostrea compressirostra*. The general aspect of this assemblage is *Lignitic*, some of the forms being found in the Gulf area in the middle, or in the middle and lower members of that division, while others range into its upper portions, and are also found at higher horizons. At the same time quite 60 feet of strata are found beneath the Aquia Creek fossiliferous beds in which as yet only a few indistinct casts of *Turritella* sp. have been observed. If the fossiliferous zones represent approximately the middle, or the middle and upper Lignitic, this lower zone (1) may he regarded in a general way as the equivalent of the lower Lignitic.

The Woodstock fauna, which is typically represented in

zone 17, embraces so far as can be determined about 45 feet at the top of the series. It contains among other Gulf forms, *Fusus (Levifusus) trabeatus*, *Solemya petricoloides*, *Corbula nasuta*, *Corbula oniscus*, *Venericardia planicosta*, *Nucula magnifica* and *Ostrea sellæformis*, the latter species increasing in number toward southern Virginia and affording thick beds on the Pamunkey and James rivers. At the same time the common forms of the Aquia Creek stage are wanting. Although not possessing the number of distinctive species found in the preceding divisions, the Woodstock stage is nevertheless in all probability the representative of the *Claiborne* of the Gulf, showing a closer parallelism, perhaps, with the beds beneath the fossiliferous sands than with the upper horizon of that division.

Between the fossiliferous beds carrying the faunas of the two stages are very nearly 125 feet of strata in which few fossils have been found outside of *Venericardia planicosta*. Many of the beds seem to be wholly barren of organic remains, while in others only a few indeterminable casts appear. No satisfactory paleontological data for correlation are therefore afforded by these deposits.

If now the Aquia Creek fauna should be held to be sufficiently similar to the Bells Landing fauna of the Gulf to warrant its restriction to that sub-stage (middle Lignitic); and the *Ostrea sellæformis* bed of the Woodstock stage, the exact equivalent of the *Ostrea sellæformis* zone of the Claiborne (middle Claiborne), then we find the 600 feet between those horizons in central Alabama represented by only 125 feet in the middle Atlantic slope and perhaps by considerably less. The representatives of the Woods Bluff and Hatchetigbee stages of the Lignitic together with the Buhrstone and lower portion of the Claiborne would thus be here included. The upper beds of the Woodstock stage might then be regarded perhaps as the equivalent of the upper Claiborne, while the 60 feet below the Aquia Creek fossiliferous beds would approximately represent the earlier portions of the Lignitic. As these lower beds are much more glauconitic than the beds above the Aquia Creek stage, they doubtless accumulated more slowly.

It is apparent, however, that the sequence of organic remains in the middle Atlantic coast Eocene does not afford the necessary data for a detailed parallelism of the subdivisions of that area with the Gulf stages. It seems altogether probable that the Pamunkey formation is the equivalent in a broad way only of the lower and middle divisions of the Eocene of the Gulf, and may even represent portions of the upper division as well. Regarding the latter reference there is little paleontological evidence, but undoubtedly less change in faunal development would be produced under the stable conditions that prevailed in Eocene time in the middle Atlantic slope than in the Gulf, so that the more highly developed fauna of the

upper portion of the series in the latter area may have existed contemporaneously with older forms outside the region. Without a much fuller knowledge of the characteristics of the Eocene fauna in the intermediate district, this cannot be definitely determined, although it seems highly probable.

Considering all the facts, the writer is strongly of the opinion that the Eocene deposits of the middle Atlantic slope represent the greater portion of the Eocene series of the Gulf, its upper members alone excepted. Compared with the section recognized by Prof. E. A. Smith, in the Alabama area, it undoubtedly comprises all or the major part of the Lignitic, Buhrstone and Claiborne and, possibly, also portions of higher horizons. This reference does not, however, necessarily involve the assumption that the basal beds of the Potomac section are the exact equivalent of the basal beds of the Lignitic, since deposition may have commenced in the one area somewhat earlier than in the other, although the difference was probably not great.

Conclusions.—1. The Eocene deposits of the middle Atlantic slope constitute a single geological unit already described under the name of the Pamunkey formation.

2. The deposits are remarkably homogeneous, consisting typically of glauconitic sands and clays which reach a thickness of nearly 300 feet.

3. Two clearly defined faunal zones are found, viz: the *Aquia Creek Stage* and the *Woodstock Stage.*

4. The Aquia Creek fossiliferous zone is approximately middle, or middle and upper Lignitic, the Woodstock zone middle, or middle and upper Claiborne. If restricted respectively to the Bells Landing sub-stage of the Lignitic and the Ostrea sellæformis bed of the Claiborne, as seems hardly probable for the reasons above cited, the 600 feet between those zones in the central Alabama area would then be represented by only 125 feet or perhaps considerably less in the Potomac region. The upper beds of the Woodstock stage might then perhaps represent the upper portion of the Claiborne while the beds below the Aquia Creek fossiliferous zone would stand as the approximate equivalent of the lower Lignitic, without however necessarily assuming that the basal beds of the Potomac section are the exact equivalents of the basal beds of the Lignitic.

5. The middle Atlantic slope Eocene, therefore, represents in a broad way all or the major part of the Lignitic, Buhrstone and Claiborne of Smith, and, when the physical conditions affecting range and migration of species are considered, perhaps even more. Both the geological and paleontological criteria are wholly inadequate for establishing the great number of local subdivisions recognized in the Gulf area, and in fact the sequence of forms indicates that no such differentiation of the fauna took place.

Art. XLIV.—*On some Ischian Trachytes;* by Henry S. Washington.

In the fall of 1894 I had occasion to visit Ischia, in the Bay of Naples, and collect the representative trachytes of the island. Most of these are too well known to need description, but some specimens from Mt. Rotaro showed a certain rather rare structure in such perfection that an account of them seems not unworthy of publication.

Mt. Rotaro is a small volcanic cone in the northeastern part of the island, some 315 meters high,* and with a well-preserved crater 107 meters deep. As far as can be seen it is composed of fragmentary material, scoriæ and blocks of trachyte and obsidian, which show stratification in places. The whole rests on marls and clays containing late Tertiary fossils.† The ridge of Mt. Tabor,‡ composed of the well known sodalite trachyte, is a lava-stream of this small volcano which has flowed to the north. According to Fuchs,§ Mt. Rotaro is the site of the great eruption of the first half of the fourth century B. C., which drove the inhabitants to the mainland.

The trachytes of Mt. Rotaro are of two kinds. One is a not very compact, light grayish-brown rock with phenocrysts of orthoclase and augite. It occurs in relatively small quantity, and under the microscope presents no features of special interest here; large phenocrysts lying in a typically trachytic holocrystalline groundmass, which shows a marked flow-structure among its component feldspar laths. Corresponding to this is a light brown obsidian, extremely brittle and somewhat vesicular, showing some orthoclase phenocrysts. Under the microscope it presents a clear, light brown glass, with rare green biotite and augite, and glassy sanidine phenocrysts, with a few feldspar microlites. Many air cavities are present.

The black trachytes and obsidians are of greater interest. For reasons which will be seen we shall begin their description with the obsidians. No. 524‖ is coal black, with a vitreous luster, very brittle, and shows numerous stout phenocrysts of glassy sanidine. An analysis by Fuchs¶ of a similar black obsidian from Mt. Rotaro is here inserted:

* This is the height given on the Government Topographical Maps; Fuchs gives 301·4, and Fonseca 277·4.

† Fonseca, Geologia dell'Isola d'Ischia, Florence 1870, 25.

‡ vom Rath, Zeitschr. d. d geol. Gesellsch. xviii, 628, 1866.

§ Fuchs, Isola d'Ischia. Florence 1873, 47; also. Tsch. Min. Mitth., 1872, 237.

‖ The numbers are those of specimens in my collection.

¶ Fuchs, op. cit., 40.

SiO_2	60·77
Al_2O_3	19·83
Fe_2O_3	4·14
FeO	2·43
MnO	Trace.
CaO	1·63
MgO	0·34
Na_2O	4·90
K_2O	6·27
P_2O_5	0·002
Ignit.	0·24
	100·55

Under the microscope the largely predominating, clear glass basis shows a rather light coffee color. The phenocrysts of sanidine are clear and not generally twinned. Inclusions are uncommon and consist of glass, magnetite and an occasional biotite, zircon or apatite. They are quite constantly surrounded by a narrow zone of deep brown glass, in which lie small prismatic microlites of orthoclase, generally at right angles to the domal and basal planes of the crystal. Besides these large feldspars are seen a few smaller phenocrysts of magnetite, green augite and biotite.

Scattered through the basis, often sporadically, but generally in clusters or irregular streaks, are small prismatic orthoclase crystals, which seldom exceed 0·05^{mm} in length, and are generally only 0·02 ^{mm} long. These are usually simple, twinning not having been seen, and only rare cases of forked forms or those brushy at the end.

They also are surrounded by a border of darker substance, or lie in large irregular patches or long streaks of this, where they occur together. This substance has no appreciable action on polarized light and shows but few signs of definite structure, though a tendency toward the formation of small spheroidal masses is noticeable under high powers, and is rendered more evident by the presence of a little globulitic dust.

When we examine the next less glassy specimen (No. 553) we find that, while the phenocrysts remain similar in general characters, the narrow dark border has disappeared and the feldspar needles have increased in number, giving rise to a fringe of fine orthoclase needles, separated from each other by extremely minute trichites and globulites. This fine narrow fringe is especially prominent on the ends of crystal sections, cut perpendicular to the plane of symmetry, the sides, as a rule, showing no such borders, but ending cleanly against the groundmass. In one case a rather small and narrow sani-

dine crystal has been cracked across and slightly bent, and from the broken edges have grown minute needles, prolonging the edges and crossing each other (fig. 1, *a*).

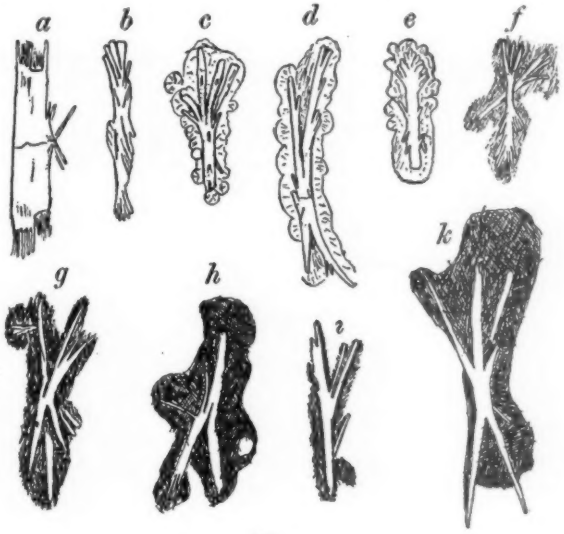


FIG. 1.

The groundmass crystals (almost solely of orthoclase), which show a decided flow-structure, have increased greatly, not only in number but in size (attaining lengths of 0·3^{mm}) and in complexity. They are seen on examination to be elongated parallel to the *à* axis. No twinned forms were seen, but almost all the small prisms show more or less forked forms, some of which are shown in fig. 1, *b*—*k*. The forms are irregular, and are rather tree or twig-like, than sheaf-like, in habit, as they do not show much tendency toward equal development of the two ends. A number of stubby brush forms are to be observed among the smallest of them (fig. 1, *e*, *f*,); and among these especially are noticed forms which are more highly developed and which resemble closely those to be described presently.

The basis proper is a clear glass, of a pale *café au lait* color, showing here and there an air vesicle. Surrounding the small forked crystals is a darker brown, slightly granular substance, which exerts some action on polarized light, as is evidenced by a very feeble aggregate double refraction. This substance also occurs in isolated spots and irregular anastomosing streaks

not inclosing crystals. A fine globulitic dust occurs in it to some extent and there is a marked tendency toward spherulitic or axiolitic forms, with a faintly developed radiated structure. This gives rise to rather mammillary or botryoidal borders around the feldspars, of which it has been attempted to give an idea in fig. 1, *c*, *d*, *e*.

The last Mt. Rotaro specimen to be described (No. 523) is properly a trachyte, not an obsidian, and it may be mentioned here that the majority of the blocks of Mt. Rotaro are of this rock or the black obsidian. It is dark-brownish black in color, of a dull luster and quite compact. There are very many white glassy sanidine phenocrysts, varying in diameter from 5 to 10^{mm}.

Under the microscope the phenocrysts are seen to be the same as in the preceding types, though augite, biotite and magnetite are rather more rare. The sanidine phenocrysts show a much greater development of the fringed borders than in the last case, and the fringe not infrequently reaches a depth of 0·5^{mm}, being usually the deeper the smaller the crystal. In some a horn is seen on each side, being a narrow continuation of the feldspar substance, with the fringe of bright needles and interstitial trichites and dust between them. These horns are sometimes slightly bent, diverging outward, and give the crystal the appearance of a shark's egg-sac ("sea-purse"). The sides also show occasionally a narrow border of fine needles and trichites, the needles lying parallel or nearly so to the crystal edge.

The groundmass consists of a colorless glass basis quite thickly sprinkled with small black grains and globulites. Its most striking feature is the great abundance of small sheaves of orthoclase needles, a development of the forms just described. These sheaves show a well marked flow-structure, in a given area, the long axes lying approximately parallel.

In length they vary from 0·2 to 0·5^{mm}, comparatively few being either longer or shorter, and their width at the widest part is about half their length. While varying considerably in details, yet the general structure is much the same. Some typical forms are shown in fig. 2, *a–h*, though the great delicacy and complexity in most cases is only roughly given.

These sheaves are composed in general of a single, straight, untwinned crystal; which at its center is narrow, but which at the ends is split up, the split portions diverging but preserving their continuity with the main body. The fission and divergence have gone on, as a rule, approximately equally at both ends, and in all directions around the axis, producing quite symmetrical forms. Besides the diverging needles which are obviously connected with the waist or main crystal, are others

which seem to be detached. Closer examination shows that most of these (if not all) are in reality of one substance with the main group, the connection being either masked by trichitic matter, or having been destroyed by the position of the plane of the section.

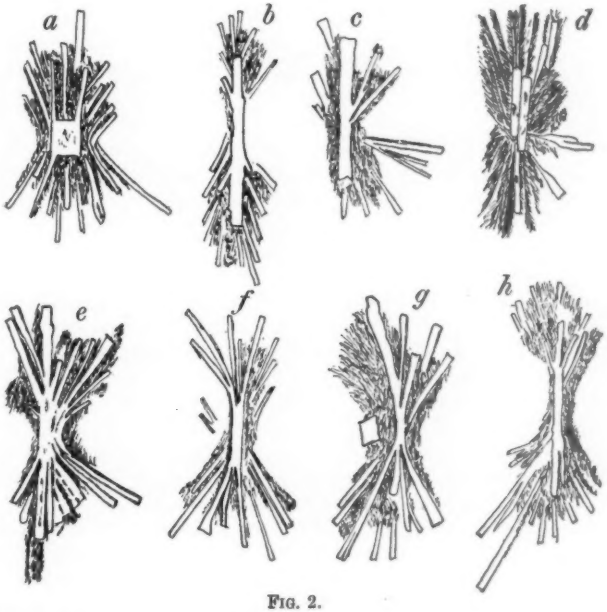


FIG. 2.

All these needles diverge at generally not large angles (up to about 30°) from the nucleus or from each other; though here and there some are seen which form angles up to 90° with the main prism. Though usually straight, or nearly so, many show marked curvature, the concavity being always outward. In some cases needles along the side form curves which are quite hyperbolic in character (fig. 2, *a*, *e*, *f*).

Between the needles lies a colorless, or very faintly brown, isotropic substance, which is very thickly sprinkled with minute globulites and curved black trichites. These bring out the structure very plainly, the colorless needles standing out bright against the dark background.

Examination with the mica plate shows that in both the nuclear prisms and the divergent needles the axis of greatest elasticity a, lies parallel to the length, and that hence the crystals are elongated in the direction of the $\dot{a}$ axis—the usual habit.

For such divergent crystal forms, which, as will presently be seen, are due to the ramification and growth of a single individual, and which correspond to the *sphærokrystalle* of Lehmann and Rosenbusch, I would propose the name *keraunoid* (Gr. κεραυνός, a thunderbolt). This word, which may seem somewhat fanciful, is chosen on account of the narrow waist and divergent, equally developed ends, with symmetry about an axis which give them a striking resemblance to ancient Greek representations of the thunderbolt of Olympian Zeus. It must be understood that the mode of formation is connoted with the term.

Besides these well-defined forms are seen in smaller number oblong spots of about the same size, of a dark gray color and dusty appearance, showing a very fine indistinct structure of parallel or slightly divergent lines. Under high powers these are resolved into bundles of colorless orthoclase needles, less clearly cut than the others, and with such a large proportion of interstitial trichitic basis that their true character is masked. It is probable that these are less well developed forms, as they show a great resemblance to the fringes at the ends of the sanidine phenocrysts. A few small clusters of needles radiating from a point are also seen—evidently sections cut through the ends of keraunoids at large angles with the axis.

The extinction of the needles is parallel or only slightly inclined, so that as the stage is revolved a rather broad dark band swings across the keraunoids, with occasionally, in the thicker ones, a short bar at right angles. In consequence of the approximate parallelism of the keraunoids due to flow-structure, the field under crossed nicols has an appearance simulating that of many spherulitic groundmasses, being sprinkled with short, thick, black bands lying parallel to one another, with here and there a thick elongated cross.

An examination of all the other Ischian slides in my possession (about seventy-five) revealed the presence of the keraunoids in only two of the blocks of black trachyte from the tufas of the Scanella Cliff, on the southwest coast, where fine sections of interstratified tufa and lava beds are exposed by wave action. One of these shows scarcely any phenocrysts, and the colorless glass basis is rather dusty. The keraunoids here are made up of much finer needles, and with more interstitial trichitic basis than in the Mt. Rotaro specimens, but the structure is quite the same. The other is much more like a normal trachyte in its groundmass, which is almost holocrystalline. True keraunoids are wanting, but many of the groundmass orthoclase crystals show divergent forms; and this may be held to be a type representative of the holocrystalline development of the glassy trachytes described above. Some

small forked orthoclase crystals were also seen in the groundmass of a black glassy obsidian from the tufa of Monte di Procida, near Cuma; and Rosenbusch* speaks of similar forms in obsidian from Ponza, though I could find none in my specimens.

In regard to the origin of these peculiar forms, it will have been evident that they are most certainly not due to twinning, and also that they cannot be referred to skeleton forms consequent upon growth along certain crystallographic axes or interaxes. They must be either an aggregation of individuals about a common central point or axis, or else due to the continuous splitting up and growth of what would be under other circumstances a compact individual.

Many cases of such ramified crystals are described and figured by Lehmann† and all the evidence points to the Ischian keraunoids being of this character, and not of the nature of aggregate growths of separate individuals. This is clearly seen on examination of the series; passing from the most glassy obsidians with small and seldom forked crystals, through the brown glassy trachyte, with individuals which are evidently split and whose diverging needles can clearly be seen to be continuous in substance with the central crystal, to the trachytes with colorless basis, where the forms have grown quite complex but in which the continuity can be made out by careful study.

According to Lehmann, the cause of this ramification is "the existence of internal tensions which cause the crystals to split here and there at the surface, producing a discontinuity which cannot be overcome by further growth. . . . . The broken parts grow independently and so form ramifications from the crystal which are no longer oriented exactly parallel to the main mass." These secondary needles may also split and ramify and thus complex forms result.

That the existence of such internal tension is a sufficient proximate cause is not to be denied, and the facts as shown by Lehmann and elsewhere apparently prove that it is the true one also. It is, however, more difficult to give the cause of the existence of such tensions; or to determine whether they are inherent in the crystal during growth under certain conditions, or whether they are due to the physical action of the magma on the crystal substance.

That the conditions were extremely local in their character is to be inferred from the few instances of ramification found among the Ischian trachytes, as well as in the Hawaiian basalts to be mentioned presently. It is scarcely possible that the

* Rosenbusch. Mikr. Phys. II, 565, 1887.

† Lehmann, Molecularphysik, Leipzig, 1888, I, 378 ff.

formation of skeleton crystals is the primary cause, as Lehmann suggests (p. 390); at least in the trachytes in question no traces of skeletal growth are to be seen, and such growth is well known to be rare in the feldspars.

That fission and ramification took place after the mass had come to rest, is to be inferred from Lehmann's conclusion (p. 380) that a certain degree of viscosity and acceleration of the crystallization is necessary to the process. It is also indicated by the extreme delicacy of the forms themselves, which would hardly be able to withstand the action of a moving magma.

The existence of the easy cleavages parallel to the base and clinopinacoid probably assisted the fission materially; and, as the prisms are elongated parallel to the axis *à*, may explain the symmetrical arrangement about an axis and not on each side of a plane.

The fringes at the ends of the sanidine phenocrysts seem to be due to the fission of feldspar substance which crystallized out of the surrounding zone and was oriented like its crystal nucleus, rather than to the fission of the phenocrysts themselves, which latter idea the sharp straight edges of the crystals decidedly disprove. The horns so often seen on either side may be due to skeletal growth, and their divergence is explained by the expansion due to fission of the enclosed feldspathic matter.

The forms just described are closely analogous to the "feather forms" assumed by augite in certain Hawaiian basalts described by E. S. Dana,* to whose kindness I am indebted for an examination of the original slides.

These augitic groups are much larger than the Ischian orthoclase keraunoids, are generally coarser, and differ as well in being much more curved and complex. Though the nuclear crystal is not, as a rule, as prominent or as constantly present in the Hawaiian forms, there cannot be much doubt but that they are due to the same cause as the Ischian—an internal tension splitting the crystal and subsequent growth enlarging it on these lines. A tendency among the augite keraunoids towards greater development at one end could be observed in many cases, which might be connected with the hemihedrism of pyroxene.†

It was also interesting to observe among these basalts, especially the finer grained ones, a tendency of the feldspars to fork and form rudimentary keraunoids somewhat resembling, though much coarser than, those seen in No. 553 of Ischia. The presence of feldspar microlites with "curved processes" apparently due to fission, and surrounded by a dark spherulitic zone, in a Hawaiian basalt glass,‡ is of great interest in this

* E. S. Dana, this Journal, xxxvii, 443, 1889.
† G. H. Williams, this Journal, xxviii, 115, 1889.
‡ Dana, op. cit., 451, fig. 5.

connection, as being very closely analogous to the Ischian forms and an evidence of the existence of internal tension in the crystals of these rocks.

Rosenbusch* mentions several cases of similar forms, and they have been described by Iddings† in a rhyolite of the Eureka District in Nevada. Analogous forms have also been noted by Herz‡ in a diabase from Guagua Pichincha, by Vogt§ in a slag, and also by H. Vogelsang.‖

It is of especial interest, however, to compare with the Ischian forms the branching feldspars observed by Iddings¶ in the Obsidian Cliff in the Yellowstone Park, and by Cross** in rhyolites of Custer Co., Colorado. The branching feldspars in these cases are orthoclase and are found as constituents of certain spherulites. Some of them are not due to fission, but are branched crystallographically and the prisms are elongated parallel to either the $\dot{c}$ or $\dot{a}$ axis in different parts of the group. Others seem from the descriptions and figures to be quite identical in nature with those of Ischia, the prisms and needles being also elongated parallel to $\dot{a}$.

The conclusions to which these two observers come regarding the structure and origin of spherulites in general are especially noteworthy. Iddings points out that we must "base the general definition of spherulitic structure on some other character than outward form," and that this fundamental characteristic is "their mode of crystallization"; spherulitic growth consisting in "the formation of radiating or diverging groups of crystals," whatever may be their outward shape, or whether the divergence takes place from one or more points or a plane.

While this definition may perhaps be thought to be in some ways too broad, (since strictly according to it we could call the radiating groups of tourmalines in granites spherulitic), yet that it applies to the larger number of true spherulites, if not all, can hardly be denied. According to this definition the Ischian (as well as the Hawaiian) keraunoids are true spherulites, though they are not groups of radiating, separate, ramified crystals, but one individual.

They are in fact, as has been said, the "*sphærokrystalle*" of Lehmann†† and Rosenbusch.‡‡ This term is not appropriate,

* Rosenbusch, Mikr. Phys., i, 36, 628; Taf. iii, fig. i; ii, 494, 548.

† Hague, Geol. of Eureka District, Mon. xx, U. S. G. S., 1892, 378, Pl. III, fig. 14.

‡ Reiss and Stubel, Reisen in S. Amer. Hochgeb. Rep. Ecuador, I, Berlin, 1892. 88.

§ Vogt. Mineralbild. in Schmelzmassen, Kristiania. 1892, 179, Pl. II, 15.

‖ Die Krystalliten, Bonn, 1875, Taf. xiv, figs. 4 and 6.

¶ Iddings, Bull. Phil. Soc., Washington, xi, 1891, 445, cf. Obsidian Cliff 7, Rep, U. S. G. S, 276 ff. 1888.

** Cross, Bull. Phil. Soc. Washington, xi, 1891, 411.

†† Lehmann, op. cit., i, 379. ‡‡ Rosenbusch, op. cit. i, 36.

as Cohen* and Cross† have pointed out; since a true, or even approximately, spherical shape is an extreme form, and one very rarely attained by the process. For this reason I suggested the use of the term *keraunoid*, which better fits the majority of the forms, and since the need of some term for this type of radiate growth seems to exist. Cross (loc. cit.) denies to such forms the right to be called spherulites, but if Iddings' definition be accepted they properly come under this head; as it is the radiate manner of growth, and not the number of individuals or the outer form which is the determining classificatory characteristic.

One can infer from the observations of these two writers, as well as from those of others and from general considerations, that true spherulites in this sense may be produced by three distinct processes. These are: by the divergence of many separate, simple, prismatic crystals from a common point or points—the most common type, especially in the smaller spherulites; by the crystallographic branching of radiating prisms, as seen in Iddings's "porous" and Cross's "hollow" spherulites; or by ramification, which may take place in only one crystal, as in the examples of Cross and Iddings. We might distinguish the two forms of this third type by the use of Tschermak's‡ terms monosomatic and polysomatic applied to meteoric chondrules. The same terms may be used for the "branched" spherulites; while those formed by the first named process are, in the nature of the case, always polysomatic. Any two, or all three, of these processes may combine, simultaneously or successively, to form complex spherulites.

In regard to the mode of growth of spherulites, Cross comes to the conclusion that, antecedent to the crystallization of the feldspar, there was a development of colloidal substance within the area of the spherulite; and that the fission of the crystals is due to the tension assumed to exist in this solidifying colloidal mass. That such a tension external to the crystal would induce strains within it, or at least aid the process of fission, seems highly probable. But apart from this an internal tension must exist in the crystal, as shown by Lehmann, and as several facts noted above (such as the curvature of the needles) go to prove.

In connection with this idea of the formation of a colloidal substance the presence of a zone of dark brown, feebly polarizing substance around individual crystals, and in patches containing many forked crystals, in the Ischian trachytes, (and in

* Cohen, Götting. gel. Anzeigen, 1886, 915.
† Cross, op. cit., 432.
‡ Cf. Cohen, Meteoritenkunde, Stuttgart, 1894, i, 260.

the Hawaiian basalt glass), is especially noteworthy.* This brown substance seems to be identical with the "supplemental spherulitic growth" of Cross (p. 424), and may be supposed to represent this colloidal substance, which in the more quickly cooled obsidian has not had time to crystalize, while in the trachyte proper (No. 523) it has entirely disappeared.

In the Colorado rhyolites Cross supposes this substance to be composed of hydrous silica and feldspar, in accordance with the chemical composition of the rock and the intimate association of quartz or tridymite with the orthoclase in the spherulites. This supposition cannot be made in the case of the Ischian trachytes, where the silica does not reach 61 per cent, and the H_2O content is less than one per cent. Here we must suppose it to have been almost entirely of feldspathic matter, with some iron which went to form the trichites.

It may be of interest to note that the ramified orthoclase crystals described in the preceding pages, as well as the Hawaiian augites, show a certain similarity to the diverging pyroxene needles forming chondrules in certain meteoric stones, as those of Montrejeau (1858), Tadjera (1867), and Tieschitz (1878), as described and shown in photographs by Meunier.† The resemblance is even greater with the artificial crystals of enstatite obtained by the same scientist and figured on page 339 of the work cited.

As I have not been able to examine sections of these falls it will not do to push the analogy far, and I can at present only call attention to their apparent resemblance, and suggest that chondrules be examined from the point of view of spherulitic growth.

* A similar brown zone may be seen about many of the spherulites in the rhyolite of the Alter Schloss, near Schemnitz, in Hungary.

† S. Meunier, Les Meteorites, Paris, 1884, 240, 242, 523.

ART. XLV.—*On numerical Relations existing between the Atomic Weights of the Elements;* by M. CAREY LEA.

IN the first part of a paper on the ions it was shown that the elements were divisible into three great classes: those whose ions were always colorless, those whose ions were always colored, and a smaller class whose ions were colored at some valencies and colorless at others.*

It was also shown that the first class, those whose ions were always colorless, could be arranged in vertical lines so that the horizontal lines contained each a natural group. Also that the elements having both colored and colorless ions were much more closely allied to these than to the group having always colored ions. This last named class does not divide into groups at all, but forms series with the atomic weights immediately following one another.

Therefore as long as an element has any colorless ions it really seems to belong to the class with the ions all colorless. So much so that when the first class is tabulated the members of this transitional class find vacant spaces into which they naturally fall. To make this clear and to elucidate what follows, I here reproduce Table II from the first part in a condensed form. (Transitionals in italics.)

I.	H 1	F 19	Cl 35·5	Br 80	J 127	----
	Li 7	Na 23	K 39·	Rb 85	Cs 132	----
II.	----	----	Ca 40	Sr 88	Ba 137	----
III.	----	----	Sc 44	Y 90	La 139	----
IV.	----	----	*Ti 48*	----	----	----
V.	----	----	*V 51*	*Nb 94*	*Ta 183*	----
VI.	----	----	----	*Mo 96*	*W 184*	----
I.	----	----	*Cu 63*	*Ag 108*	*Au 196*	----
II.	Be 9	Mg 24	Zn 65	Cd 112	Hg 200	----
III.	B 11	Al 27	Ga 69	In 114	*Tl 204*	----
IV.	C 12	Si 28	Ge 72	Sn 118	Pb 206	Th 234
V.	N 14	P 31	As 75	Sb 120	*Bi 208*	----
VI.	O 16	S 32	Se 79	Te 125	----	----

In the case of some few elements it has not been easy to find published data sufficient to determine with absolute certainty the color of the ions. Further study of this subject has led me to make a slight change in reprinting the above table. I had previously classed the metal cerium as transitional. The ceric ion is undoubtedly colored, but as to the cerous ion there is some uncertainty. Its compounds are nearly colorless, but as they exhibit a slight red tinge the ions may perhaps be colored. It, therefore, seems better in this uncertainty to place cerium

* This Journal, May, 1895; the second part will appear next month.

alongside of the other members of its group. It is, therefore, omitted from the above table. Also in the paper just referred to gold was placed amongst the elements having colored ions only. The auric ion is certainly colored, but about the aurous ion there is some doubt; the oxids and the haloids are colored but as they are insoluble they give no positive information. It appears, however, that when aurous chloride is dissolved in sodium chloride it yields a colorless solution from which colorless crystals are obtained. Various other double salts form both colorless solutions and colorless crystals. The following are examples: Ammonium aurammonium sulphite, sodium aurothiosulphate, potassium aurocyanide, etc.*

As it seems characteristic of the soluble salts to be colorless, I conclude that gold must be considered as having both colored and colorless ions. It is, therefore, a transitional element and finds its place in the above table where elements of that class appear in italics. It is, however, interesting to observe that just as these two metals cerium and gold are at the very limiting point between two classes, so there are spaces open for them in each of these classes, a circumstance that can hardly be fortuitous.

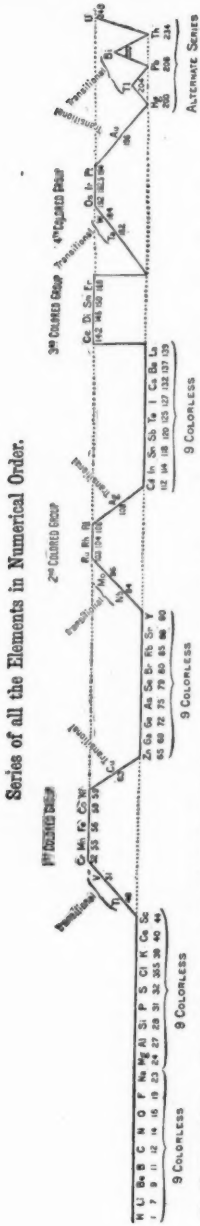
Table of Differences.

If the respective numbers of the first column in the preceding table be each subtracted from the corresponding number of the second column, the second column from the third and so on, we obtain a series of differences which are given in the table below.

18	16·5	44·5	47
16	16	46	47
----	----	48	49
----	----	45	49
----	----	44	88
----	----	----	88
----	----	45	88
15	41·3	46·7	88
16	42	45	90
16	44	46	88
17	44	45	88
16	47	46	----

It has been remarked, I think as far back as the time of Dumas that differences of 16 between the atomic weights frequently presented themselves and occasionally differences of forty-five or thereabouts. But these were scattered cases. In the above table of differences *all* the elements are represented with the exception of the comparatively small group having ions always colored. As has been already said, this

* Roscoe and Schorlemmer, 1st ed., ii, 2, pp. 380–1.



last group of elements having nothing in common with other elements cannot be classed with them and will probably be found, when we know much more than we do now, to have a wholly different constitution.

There are several things worthy of remark in the above table. It will be seen that the differences at first approximate to 16. Then comes a long set of differences, twenty in number, beginning with 41·3 and gradually but not regularly increasing to 49. The remaining differences are all exactly 88 with one exception of 90, but as this is the difference between two metals of which comparatively little is known and whose atomic weights cannot be considered as being accurately fixed (indium and thallium), it is quite probable that this exception may hereafter disappear.

It should be remarked that when the set of differences approximating 16 is once left behind, this difference does not reappear in a single case. The same is true of the differences averaging 45: this class of differences does not once reappear when 88 is reached.

For some time past it has been believed that the oxygen group does not end with tellurium but contains still another member with a higher atomic weight. It will be observed that in both the above tables there remains a space for such an element. Its atomic weight should exceed that of tellurium by the difference 88 and should therefore be 213. Finally it may be said that the blanks in the table of differences are due to corresponding blanks in the table of atomic weights.

The change just mentioned in the classification of cerium and of gold makes a slight change in the table representing the whole range of elements in series. I therefore reproduce this table as corrected.

It will be observed that all the elements having only colorless ions appear on the base line. The elements having ions always colored appear on the upper line parallel to the base line. The transition elements appear on the inclined lines.

Art. XLVI.—*Crocoite from Tasmania;* by Charles Palache.

Through the kindness of Mr. Stephen A. Douglas of San Francisco, the writer came into possession some time since of specimens of crocoite from Tasmania representing, so far as his information extends, a new or undescribed locality for this mineral. Of the two specimens available for study one is now in the mineral cabinet of the University of California, the second in the writer's possession. They consist of masses of crocoite crystals clustered upon bases of lamellar limonite, each mass measuring several inches in diameter. The mineral occurs in a silver-bearing lead deposit known as the Adelaide mine on Mt. Dundas, west coast of Tasmania; but of the nearer geological relations unfortunately no information is at hand. It is said to occur in considerable abundance, a statement borne out by the appearance of these specimens and the many others in Mr. Douglas's possession. Besides the limonite there is no trace of gangue or wall rock nor are there any other lead minerals such as might be expected to accompany the crocoite.

The crystals are of a light hyacinth red color, quite translucent and with adamantine luster. They vary in size from minutest needles to prisms of 2^{cm} length and 3^{mm} diameter. The habit is prismatic and the crystals are never doubly terminated, being attached at one end to the limonite. The larger crystals are often cavernous, giving rise to hollow prismatic forms. As is usually the case with crocoite, the crystal planes are even and brilliant, giving good reflections on the goniometer. The faces of the prism zone are, however, strongly striated parallel to the prism edges and this renders the identification of some forms doubtful.

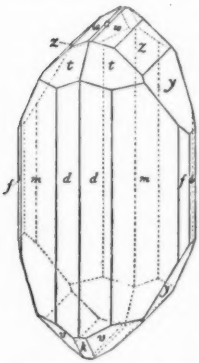
Four crystals were subjected to measurement and showed the following forms, most of which were present on each crystal. The letters used are those of Dana.

m	(110)	I	*k*	($\bar{1}$01)	1–$\bar{1}$
f	(120)	i–2	*z*	(011)	1–i
d	(210)	i–$\bar{2}$	*w*	(012)	$\frac{1}{2}$–i
*S	(10·3·0)	i–$\frac{10}{3}$	*y*	(021)	2–i
*T	(530)	i–$\frac{5}{3}$	*t*	(111)	–1
b	(010)	i–i	*v*	($\bar{1}$11)	1
c	(001)	*o*			

The following table shows some of the measurements and the angles calculated from Dauber's elements.

		Calculated.	Average measurement.	Number of times measured.	Limits.
$m \wedge m^3$	$110 \wedge 1\bar{1}0$	86° 19′	86° 14′	14	85° 59′–86° 31′
$z \wedge z'$	$011 \wedge 0\bar{1}1$	83 37	83 38	1	
$w \wedge w'$	$012 \wedge 0\bar{1}2$	48 11	48 12	1	
$y \wedge y'$	$021 \wedge 0\bar{2}1$	121 35	121 40	1	
$k \wedge v$	$\bar{1}01 \wedge \bar{1}11$	36 9	35 41	1	
$T \wedge b$	$5{\cdot}3{\cdot}0 \wedge 010$	60 38	59 55	1	
$S \wedge b$	$10{\cdot}3{\cdot}0 \wedge 010$	74 17	74 13	3	73°–75° 15′

The two prisms (10·3·0) and (5·3·0) were represented by exceedingly indistinct faces, reflections from which were only dimly visible with the δ ocular of the Fuess instrument. On this account they are considered doubtful and are not introduced into the figure. The first form S (10·3·0), is unrecorded; the second, T (5·3·0), is enumerated among doubtful forms by Dauber.



The remaining forms are shown in the figure in about an average development; but their proportions vary widely in various crystals with either t (111), v ($\bar{1}11$) or forms of the clinodome zone predominating. This combination of forms is exceedingly like that shown by Dauber* on a crystal of crocoite from Berezov in the Ural, which is somewhat surprising considering the widely different paragenesis of the mineral in the two localities.

Mineralogical Laboratory, Harvard University, January, 1896.

* Berichte Akad. Wien., xlii, fig. 93, Pl. II, 1860.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Investigations with sulphide of nitrogen.*—In a preliminary notice, Clever and Muthmann have described a few products obtained by the action of several reagents upon this well-known explosive compound. The substances obtained are so remarkable in composition and behavior that it is evident that the authors have opened up an important field of investigation. By determining the elevation in boiling-point of the carbon disulphide solution, the authors have confirmed the recent results of Schenck, who used the depression of the freezing-point in naphthalene solution, in arriving at a molecular weight 184 for sulphide of nitrogen, corresponding to the formula N_4S_4. By the action of an excess of bromine upon a solution of nitrogen sulphide in carbon disulphide, a well crystallized, bronze-colored compound, $N_4S_4Br_4$, was obtained. By exposure to the air, the substance just mentioned loses sulphur bromide by evaporation and is changed into a yellow amorphous compound, probably having the composition $N_4S_5Br_2$. If bromine vapor is allowed to act upon dry nitrogen sulphide, it is greedily absorbed, liquefaction takes place and after some time large garnet-red crystals of a very unstable body with the composition $N_4S_4Br_6$ are formed. By exposure to the air this substance yields the previously-mentioned yellow amorphous body. The most interesting compounds, however, are those which will be now mentioned. By the action of nitrogen dioxide (NO_2) upon a solution of nitrogen sulphide in carbon disulphide, a very deliquescent, white crystalline compound, probably NSO_4, is produced. It reacts with water with the evolution of NO and the formation of sulphuric acid, probably according to the equation,

$$NSO_4 + H_2O = NO + H_2SO_4.$$

Upon acting upon the previously-mentioned substance, $N_4S_4Br_4$, while suspended in carbon disulphide, with nitrogen dioxide, a canary-yellow substance is deposited in microscopic crystals. This is free from bromine and probably has the composition represented either by the formula NSO or $N_3S_3O_4$. This compound decomposes suddenly, giving forth a brilliant light, even when a tube containing it is exposed to the heat of the hand. It dissolves in water, giving a yellow, neutral solution, which, upon warming, deposits a black substance. The latter quickly decomposes into sulphur and a gas of peculiar odor, which has not yet been investigated, but which the authors surmise to be a lower oxide of sulphur. The canary-yellow compound behaves in a different manner with alcohol, giving a dark red solution which gives off sulphur dioxide upon boiling and deposits a crystalline substance which had not yet been analyzed. Another curious

substance, probably $N_4S_3O_6$, was obtained by the action of nitrogen dioxide upon $N_4S_5Br_2$. The authors intend to complete the study of the substances that have been mentioned, and to extend the investigation to the action of chlorine, iodine and the chlorides of phosphorus upon nitrogen sulphide.—*Berichte*, xxix, 340. H. L. W.

2. *Manganese carbide.*—Moissan has prepared, by means of his electric furnace, a well-characterized compound CMn_3. This result confirms that of Troost and Hautefeuille, who obtained the same substance by the use of a wind-furnace. Moissan used 200 parts of manganese protosesquioxide and 50 parts of sugar charcoal and heated the mixture in a carbon tube, closed at one end. The compound is readily attacked by various chemical agents, and the action of water upon it is especially interesting from the fact that equal volumes of marsh-gas and hydrogen are evolved. The following equation represents the reaction:

$$CMn_3 + 6H_2O = 3Mn(OH)_2 + CH_4 + H_2$$

No acetylene or ethylene is produced.—*Compt. Rend.*, cxxii, 421. H. L. W.

3. *The preparation of pure strontium compounds.*—Sörensen has made a critical study of various methods of obtaining strontium salts free from barium and calcium. The process which he recommends, after an elaborate series of experiments, is briefly as follows: The greater part of the barium is removed by adding concentrated hydrochloric acid to a solution of the chlorides until strontium chloride begins to crystallize out upon cooling. A precipitation by means of sulphuric acid is then made in the hydrochloric acid solution, whereby most of the calcium is left in solution. The sulphates are decomposed by warming with strong ammonium carbonate solution, the washed carbonates are dissolved in nitric acid, the solution is evaporated to dryness, the residue is dissolved in water and filtered, and the barium is completely removed by repeated fractional precipitations with small amounts of dilute sulphuric acid in a solution containing $\frac{1}{10}$ of its volume of 66 per cent nitric acid. This separation is not considered complete until the last precipitate of sulphate is free from barium. The nitrate solution is evaporated to a semi-solid condition, the mass is extracted with alcohol and the residue is washed with the same liquid. This residue is dissolved in water and the operation is repeated until the calcium has been completely removed. The author obtained a yield of 76–77 per cent by this method.

The author calls attention to a rule which has an important bearing upon the separation of barium, strontium and calcium compounds from each other. He considers the rule to be quite self-evident, but he believes that it has not always been taken into consideration in the preparation of chemical products. It is expressed by the statement that "Corresponding, isomorphous salts of closely-related elements are more difficult to separate than

corresponding salts which are not isomorphous." As examples, the author notices that he was unable to completely separate strontium chloride from calcium chloride, although the two salts, separately, have an entirely distinct behavior when concentrated hydrochloric acid is added to their solutions. On the other hand, barium and strontium chlorides, although their behavior with concentrated hydrochloric acid is similar, can be readily separated so as to obtain pure barium chloride, because these salts are not isomorphous. Calcium nitrate, having a crystalline form which is distinct from that of barium and strontium nitrates, can be separated from the latter. The sulphates of calcium, strontium and barium are isomorphous, but although they differ considerably in their solubility, for instance in dilute hydrochloric acid, and in their stability towards the alkali-carbonates, it is nevertheless impossible to separate them when they are precipitated together, and not each by itself.—*Zeitschr. Anorg. Chem.*, xi, 305–378. H. L. W.

4. *A new class of compounds of metallic salts with ammonia.*—WIEDE and HOFMANN have described the salts $C_2S_7Co_2(NH_3)_6$, $CS_2Ni(NH_3)_2$, and $C_2S_7Fe_2(NH_3)_6 2H_2O$, which are evidently derivatives of thiocarbonic acid, and members of a new class of the interesting metallic-ammonia salts. The simplest method of preparing the compounds is by the action of aqueous ammonia and carbon disulphide upon the metallic hydroxides. The cobalt and iron salts are black while the nickel compound has a ruby red color, and all of them were obtained in a well crystallized condition. It is remarkable that iron forms such a compound.—*Zeitschr. Anorg. Chem.*, xi, 379. H. L. W.

5. *Influence of light on the form of discharge of a Holtz machine.*—ELSTER and GEITEL have shown that the brush and spark discharge of a Holtz machine, between a spherical anode and a disc cathode, can be made to disappear under the influence of ultra violet light. A concave disc of amalgamated sheet zinc constitute the negative poles. When sparks are passing between the sphere and the disc, they can be made to disappear by lighting a piece of magnesium ribbon in the neighborhood of the cathode. When the magnesium light no longer illuminates the cathode the sparks reappear. In this case the illumination restricts apparently the discharge instead of increasing it. Elster and Geitel return to the consideration of this phenomenon, and conclude that the brush discharge and spark of a Holtz machine is supplanted by a glow discharge when the cathode is illuminated, and that this last form of discharge carries over a less quantity of electricity than the brush and spark discharge in the dark.—*Ann. der Physik und Chemie*, No. 3, pp. 401–407, 1896. J. T.

6. *Fluorescence of Vapors.*—E. WIEDEMANN and G. C. SCHMIDT state that sodium and potassium vapor fluoresce brightly, the first green and the last red. The fluorescence spectrum of sodium vapor gives continuous and also channelled bands, together with the sodium line. Sodium and potassium vapor show also

under electrical excitation of fluorescence continuous bands in the green and also the red. Stokes' law apparently applies to the fluorescence of metallic vapor, and the fluorescence of the latter affords a means of explanation of various astrophysical phenomena. —*Ann. der Physik und Chemie*, No. 3, pp. 447–453, 1896. J. T.

7. *Interference of Electric Waves.* — VIKTOR VON LANG employs Quincke's well known double U-tube form of apparatus for showing the interference of sound waves to exhibit also the interference of electrical waves. Righi's apparatus is used to generate short electric waves. These waves are sent into the Quincke tube and by suitably changing the length of the arms of the tube, interference is produced which is detected by a species of *coherer* such as was used by Branly, and developed by Lodge. One arm of the Quincke tube was also partially filled with certain dielectrics and their index of refraction measured. The value of the latter for paraffine was $\mu = 1{\cdot}701$. Righi obtained $\mu = 1{\cdot}43$. For sulphur $\mu = 2{\cdot}333$, while Righi obtained $\mu = 1{\cdot}87$.—*Ann. der Physik und Chemie*, No. 3, pp. 430–442, 1896. J. T.

8. *Röntgen's Discovery.*—Since the last issue of this journal considerable progress has been made in the art of cathode photography. Greater detail has been obtained by what are called focus tubes, which consist in the main of a modification of that form of Crookes tube which was employed to show the convergence of the cathode rays proceeding from a concave metallic mirror, upon a thin sheet of platinum placed at its focus. When this sheet of platinum is inclined at an angle of 45° to the line connecting the cathode and the anode, it apparently serves as a center from which sharp shadows are obtained. It seems probable also that the anode reflects the cathode rays in a similar manner. Tesla, and O. N. Rood bring forward evidence to show that the cathode rays can be reflected. Tesla early stated that it was best to use one terminal of a high-frequency coil. I have found this method of great advantage in diminishing the liability to breakage of the tubes. A wire is led from one terminal of a Thomson or Tesla coil to one terminal of a Crookes tube, the other terminal of which is connected to a large metallic plate. The system should be brought into resonance. The method, however, presents this difficulty. The high electromotive force and the electrical oscillations drive out the occluded air and the tubes require to be re-exhausted. It is desirable, therefore, to have the tubes always connected with a mercury pump, or to exhaust the tubes originally by the aid of a high-frequency coil. Tubes which have been electrically excited by the ordinary Ruhmkorf coil while being exhausted soon depreciate under the action of the high-frequency coil. J. T.

9. *The Temperature of the Carbons of the Electric Arc.*— WILSON and GRAY in a paper before the Royal Society give the results of measurements of the temperature of the positive pole of the electric arc. The temperature obtained was

3600° abs. or 3300° C.

This agrees very closely with the approximate estimate given by Violle (1893), viz.: 3500° C. The method here employed is that used by the same authors in an earlier investigation on the effective temperature of the sun (Phil. Trans., A., vol. clxxxv, 361, 1894). This consisted essentially in balancing the radiation from a platinum strip against that of the carbon of the arc. Further, taking 3300° as the temperature of the crater of the positive carbon, that of the *negative* carbon is found to be about 2400°. No estimate is attempted of the temperature of the arc itself.—*Proc. Roy. Soc.*, lviii, 24.

10. *Melting points of some of the metals.*—S. W. HOLMAN, R. R. LAWRENCE and L. BARR have recently given the following determinations of the melting points of several of the metals, which they believe to be more reliable than previous data. The values are based upon 1072° C. as the melting point of gold, as given by Holborn and Wien. They are as follows:

Aluminum	660°
Silver	970°
Gold	[1072°] assumed
Copper	1095°
Platinum	1760°

All of the samples experimented upon were of a high degree of fineness except the platinum, which may have contained 0·5 p. c. of impurity. The paper, from which the above data are quoted, gives in full the method of experiment followed. Other papers by S. W. Holman, also recently published in the *Proceedings of the American Academy*, have the subjects: Calorimetry, methods of cooling correction; also Pyrometry, calibration of the Le Chatelier thermo-electric pyrometer.

II. GEOLOGY AND NATURAL HISTORY.

1. *Economic Geology of the Mercur Mining District, Utah;* by J. EDWARD SPURR, with introduction by S. F. Emmons. Sixteenth Annual Report of the United States Geological Survey, Part II, pp. 343–454. (Author's abstract.)—The Oquirrh mountains are one of the parallel ranges of the Great Basin, and the first lying west of the Wasatch range and the Great Salt lake. Close to the southern end of this range the Mercur mining district is situated, in a well-marked topographical basin which has been called the Mercur basin. The rocks exposed in the Mercur basin consist of about 12,000 feet of strata, chiefly massive limestones with intercalated calcareous sandstones and occasional shale beds; fossils from various points in this series show it to be all of Carboniferous age. In the lower part there are intruded sheets of quartz porphyry of two distinct varieties. With one of these varieties, which has a distinct granophyric structure, all of the ore deposits of the district are associated. In the productive region this porphyry is reduced to three sheets, averaging

ten or fifteen feet in thickness, and within one hundred feet of each other. The lowest sheet is characterized by the presence of silver ores, to the exclusion of gold; the middle sheet by gold ores, with no silver; while the uppermost sheet, which is especially thin and intermittent, is not mineralized to any extent. The gold and silver horizon are known as the Gold and Silver Ledges respectively.

The Silver Ledge is marked by complete silification of the limestone, and by barite in irregular masses, with some stibnite and a little copper and silver. It is probable that the metals were originally deposited as sulphides, and that they were introduced into their present position, together with quartz and barite, by ascending waters; and the phenomena accord best with the idea that the mineralization was accomplished by waters excluded from the porphyry during its consolidation, and that thus the ore-deposit is a special case of contact-metamorphism.

The Gold Ledge, which is situated about one hundred feet vertically above the Silver Ledge, is characterized by a softened condition of the ores, whether in the normal condition of sulphide, or in the zone which has been bleached and altered by surface oxidation. Its most characteristic feature is realgar, which occurs in large amounts in the unoxidized ores, with frequent cinnabar and gold in small, but in certain zones nearly uniform, quantities. The gold is in extremely finely divided condition; but it is probable that it exists in the unaltered form as telluride, and that on oxidation it has become free gold. Evidence shows that the mineralization of the gold-horizon took place at a distinctly later date than that of the silver-horizon; and that the mineralizing agents were probably in a vaporous rather than in a liquid form.

2. *Catalogue of the Fossil Fishes in the British Museum, Part III, containing the Actinopterygian Teleostomi of the orders Chondrostëi (concluded), Protospondyli, Aetheospondyli, and Isospondyli (in part)*; by A. S. Woodward; pp. 1–544, pls. I–xviii. London, 1895.—Mr. Woodward's introduction, of about twenty pages, is full of important conclusions, derived from his exhaustive study of the Actinopterygian fishes, regarding the phylogenetic relations of the several families. In the arrangement of the material in the catalogue, the author has attempted to record, in as nearly a natural order as possible, the variation of each type at the time of its dominance. The origin of the Chondrostëi is obscure, but that they are later than the Crossopterygians is evident. When they first became dominant in the lower Carboniferous they exhibited a remarkable sense of modification and thereafter suffered very little essential change. The genus *Acentrophorus* of the upper Permian is the first of the sub-order Protospondyli, and it is observed to be the most generalized member of the family to which it belongs (Semionolidæ) which is also the most generalized family of its series.

The same fact is noted regarding *Ophiopsis*, the most generalized genus of the family Macrosemeidæ, and the earliest to appear.

The Pycnodontidæ, specially on account of the character of the axial skeleton and the mandible, are placed among the Protospondyli.

The author is led to place little value upon the characters of the scales for purposes of classification. The combination of thick, rhombic, firmly-articulated scales of the abdominal region with delicate, cycloidal, deeply-overlapping scales of the caudal pedicle in the interesting genus *Aetheolepis* of New South Wales, and the second case of *Tetragonolepis* having both thick and thin scales, furnish a good reason for departing from the long established usage in this respect.

Attention is also called to the interesting fact that the higher fishes, like the highest of terrestrial vertebrates, are characterized by a comparatively simple mandible. And the author remarks in this connection that, "on acquiring this simplication of the jaw, the Teleostomes seem to be infused with new vigor, vertebral centra invariably occur, at first as simple rings, then as robust amphicœlous bodies; and a still more varied series of families arises, including analogies of all the principal modifications observed among the lower races, these being superinduced upon the new and advanced type of skeletal frame." H. S. W.

3. *Catalogue of the Mesozoic Plants in the Department of Geology of the British Museum. The Wealden Flora. Part II.—Gymnospermæ;* by A. C. SEWARD; pp. 259, plates XX. London, 1895.—The following quotations from Mr. Seward's conclusion drawn from the study of this material will be of interest to the geologist: "The general characters of the vegetation would certainly seem to point to a tropical climate," p. 239.

"The evidence of palœobotany certainly favors the inclusion of the Wealden rocks in the Jurassic series," p. 240.

Regarding the evolution of angiospermous plants, he says: "The true Wealden vegetation would seem to have been without any examples of the highest class of plants, and may be looked upon as the last of the Mesozoic floras in which gymnosperms represented the limit of plant development. One genus, however, carries us a few steps towards the next stage in botanical evolution; the inflorescence of *Bennettites* marks a distinct advance in the differentation of reproductive structures beyond the characteristic cycadean type," p. 241.

4. *Catalogue of the Perciform Fishes in the British Museum, 2d edition, Vol.* 1, *containing the Centrarchidæ, Percidæ, and Serranidæ (part);* by GEORGE A. BOULENGER: pp. 394, pls. XV. London, 1895.—The materials forming the basis for this second edition are the collections received by the museum since the year 1870. At the time of the publication of the first edition 29,275 specimens had been registered. The acquisitions since that time amount to 29,375 specimens. These have been obtained from all parts of the world; among the most important contributions are those brought home by the "Challenger," comprising littoral, pelagic, and bathybial forms from almost every part of the ocean

traversed by the ship. Also fresh-water specimens from out of the way places in Asia, Africa, South and North America and the isles of the seas. The author has given special attention in his revision to the study of the osteological characters, and the chief types of cranial structure are illustrated by figures in the text. Special acknowledgments are made of the assistance derived from the revisions of North American ichthyology by our countrymen Jordan, Gilbert and Eigenmann. For the families studied the report gives a thorough revision of present knowledge.

5. *Descriptive Catalogue of the Spiders of Burma, based upon the Collection made by Eugene W. Oates and preserved in the British Museum;* by T. THORELL; pp. 406. London, 1895.—This is an exhaustive descriptive catalogue, in Latin, of this unique collection containing 310 species, of which 206 are new to Burma and 153 new to science.

6. *The duration of Niagara Falls and the History of the Great Lakes;* by J. W. SPENCER; pp. 1–126, figs. 1–27, pls. i–v. (2d ed.)—This is an excellent series of papers explaining the geological features and history of Niagara Falls and environs and republished in book form under the direction of the Commissioners of the N. Y. State Reservation at Niagara and accompanying their eleventh report. The chapters, nine of them, were originally published by Dr. Spencer in this and other journals; to them are added a few full-page reproductions of photographs of the falls and river.

7. *Illinois State Museum.* Bull. No. 7.—New and interesting species of Paleozoic fossils. pp. 1–89, pls. i–v, Dec. 5, 1895. Bull. No. 8.—Descriptions of new and remarkable fossils from the Paleozoic rocks of the Mississippi valley; pp. 1–65, pls. i–v, Feb. 1896.—In these two bulletins the authors, S. A. MILLER and WM. F. E. GURLEY, have described and figured a large number of specimens of fossils, chiefly crinoids, and from Niagara, Hamilton and various Carboniferous formations, in large majority from the latter.

8. *Oblique Bedding in Limestones.*—A remarkable structural condition is described by Professor Calvin in the Le Claire limestones of Iowa.* This limestone is the second stage of the Niagara formations of that state. The author states: "In the first place it varies locally in thickness, so much so that its upper surface is exceedingly undulating, the curves in some places being very sharp and abrupt. In the second place it differs from every other limestone of Iowa in frequently exhibiting the peculiarity of being obliquely bedded on a large scale, the oblique bedding often affecting a thickness of fifteen or twenty feet. The phenomena suggest that during the deposition of the Le Claire limestone the sea covered only the southwestern part of the Niagara area, that at times the waters were comparatively shallow, and that strong currents, acting sometimes in one direction

* The Le Claire Limestone by Samuel Calvin, Bull. Lab. Nat. Sci. State Univ. Iowa, vol. iii. pp. 183–189, pls. i–ii, Mch. 16, '96.

and sometimes in another, swept the calcareous mud back and forth, piling it up in the eddies in lenticular heaps or building it up in obliquely-bedded masses over areas of considerable extent. The oblique beds observe no regularity with respect to either the angle or direction of dip. Within comparatively short distances they may be found inclining to all points of the compass."

9. *Geological History of the Chautauqua (N. Y.) Grape Belt;* by R. S. TARR.—Under this title, Bulletin 109, of the Cornell University Agricultural Experiment Station, publishes some topographical and structural facts regarding the land bordering the eastern end of Lake Erie, which will be of interest to students of surface geology.

10. *Geological Literature.*—The assistant librarian of the London Geological Society has prepared a second pamphlet under the above title, containing a list of the geological literature added to the library during the year ending December 31, 1895. It contains a full subject index as well as list of titles of papers arranged alphabetically by authors. Although not exhaustive (157 pages), it is a convenient reference catalogue.

11. *Norges Geologiske Undersögelse.*—The following are recent publications from the Geological Survey of Norway:

No. 10. Tagskifere, heller og vekstene; af Amund Helland.
No. 11. Lagfölgen på Hardangervidda ogden såkaldte "böjfjeldskvarts;" af W. C. Brögger.
No. 12. Norges granitindustri af Carl C. Rüber.
No. 13. Gausdal. Fjeldbygningen inden rektangelkartet Gausdals omraade; af K. O. Björlykke.
No. 14. Aarbog for 1892 og '93; udgivet af Dr. Hans Reusch, undersögelsens bestyrer.
No. 15. Dunderlandsdalens jernmalmfelt (i Ranen, Nordlands amt, lidt sönden-for polarkredsen); af J. H. L. Vogt.
No. 16. Jordbunden i Jarlsberg og Larviks amt; af Amund Helland.
No. 17. Nissedalens jernmalmforekomst (i Thelemarken); af J. H. L. Vogt.

12. *Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol;* von W. C. BRÖGGER. (Vidensk. Skrift. i Math. natur. Klasse, Kristiania, 1895, 8° 183 pp.)—In this publication, which is part two of the series (part I, Grorudit-Tinguait Serie) by Prof. Brögger on the eruptive rocks of south Norway, the author mentions that having undertaken an expedition into Southern Tyrol—a region classic in geological history—for purposes of study and comparison, he has been led to publish his observations and to draw some general conclusions from them.

He first shows that "the typical rocks of Monzoni and Predazzo are not syenites, nor are they diorites (or diabases or gabbros) but *monzonites.* They form a well-characterized and particular group of rocks, which are distinguished by the fact that they occupy an intermediate position between the alkali-orthoclase rocks on the one hand and the plagioclase rocks, rich in lime and poor in alkali, on the other. The monzonites are sharply defined orthoclase-plagioclase rocks." The relations are shown in the following table, where the monzonite group is inserted between the alkali series and the lime series.

Orthoclase rocks.		Orthoclase-plagioclase. Monzonite group.		Plagioclase rocks.	
% SiO_2		% SiO_2	Acid quartz monzonite. (*adamellite*)	% SiO_2	Acid quartz diorite.
67–82	Granite.	67–73		66–72	(Tonalite.)
63–66	Quartz-Syenite. (Nordmarkite, etc.).	63–66	Medium acid quartz monzonite. (*Banatite.*)	63–65	Medium acid quartz diorite.
50–62	Syenite. (Plauenite, Laurvikite, etc.).	49–62	*Monzonite.*	48–62	Diorite.
		46–52	*Olivine-Monzonite*, etc.	44–53	Gabbros, etc.

Peripheral portions of the masses at Predazzo, composed of pyroxenites, are regarded as differentiation products in place, while dikes of camptonite and complementary feldspathic rocks (liebnerite poryhyry) are mentioned.

The order of succession of the various magmas at Monzoni and Predazzo is discussed very fully and in connection with that of the rocks of South Norway. In carrying out the discussion a notable contribution to the origin of granite and the mechanics, etc., of laccolith formation is added with illustrations drawn chiefly from the south Norwegian localities.

The author believes that in endeavoring to discover the law of succession of eruptive magmas it is wrong to confound the abyssal and effusive rocks together, since the two do not of necessity correspond. "The order of succession, basic, less basic, acid, appears in fact with abyssal rocks to occur so commonly that we must regard this succession as the normal one; the sudden recurrence to basic is known in many localities, but appears just as often to be lacking."

A very thorough digest of the literature is given and it can be truly said that in the light of the new petrology the author has cleared up and put in order a vast mass of confused and often contradictory information about this well known locality in the Tyrol. Field geologists as well as petrographers will find the work replete with fruitful and suggestive ideas. L. V. P.

13. *Mica-Peridotites in Bengal.*—In two short papers by Mr. T. H. Holland (Records Geol. Surv. India, vol. xxvii, 1894, Pt. 4, p. 139 seq.), some interesting occurrences of mica-peridotites are given; one of them, which contains over eleven per cent of apatite, appears to us of especial interest in connection with Vogt's work on apatite deposits (Zeitschr. für prakt. Geol., Nov., Dec., 1895). Several varieties of these rocks are described, some of which break up through coal-bearing strata. L. V. P.

14. *Zusammenstellung petrographischer Untersuchungsmethoden nebst Angabe der Literatur*, by E. Cohen. 3d edition, 53 pp. Stuttgart, 1896.—This little pamphlet, which contains a very full bibliography of the literature pertaining to the various methods of petrographic investigation and discrimination of rock-forming minerals, will be found a very useful addition to the working library of every mineralogist and petrographer. L. V. P.

15. *Jadeite from Thibet*, by MAX BAUER, Jahrb. für Min., 1896, i, p. 85.—In studying some specimens of jadeite from an unknown locality in Thibet, Prof. Bauer has made the very interesting discovery that the mineral is a component of a rock composed of jadeite, plagioclase and nephelite; at times the jadeite predominates to the extent of practically supplanting the other components. The author remarks that if the jadeite at this locality is, as elsewhere, a member of the family of crystalline schists, then we have here an entirely new method for the occurrence of nephelite, until now restricted to eruptive rocks.

It appears to us, however, that this interesting occurrence of nephelite may prove to be of great importance in explaining the origin of jadeite, whose significance in the crystalline schists has never been understood, and it may also furnish one explanation why, among all the varieties of metamorphosed igneous rocks occurring among the crystalline schists, those containing nephelite have not been found. L. V. P.

16. *A Dictionary of the Names of Minerals including their History and Etymology;* by ALBERT H. CHESTER. 320 pp., 8vo. New York, 1896 (Wiley & Sons).—The author gives in this work, to which it is evident that he has devoted a vast amount of careful, patient labor, the most complete history of the names of mineral species that has ever been attempted. How fruitful his efforts have been will be appreciated from the fact that of nearly five thousand names included, full information with reference to the original authority, also derivation and so on, is given in the case of all but about one hundred and fifty. This work will be highly valued by all mineralogists interested in the history of their science, and will be useful to many others, including those concerned with the etymology of English words in general.

17. *Minéralogie de la France et de ses Colonies:* Description physique et chimique des Minéraux, Étude des conditions géologiques de leurs gisements; par A. LACROIX. Tome Premier (2 Partie), 723 pages. Paris, 1895 (Baudry et Cie.).—The first part of Professor Lacroix's important work was noticed nearly three years since (vol. xlvi, p. 76), and its originality in scope and method remarked upon. The part now issued concludes the first volume and carries the subject on from the micas through the pyroxenes and amphiboles. All interested will look forward with interest to the final completion of the entire work.

18. *Mineralogy;* by FRANK RUTLEY. Eighth edition, revised and corrected, 240 pp. London, 1887 (Thomas Murby).—This little book must have been an aid to many in acquiring a knowledge of elementary mineralogy, for since its first appearance it has gone through numerous revisions and the eighth edition is now given to the public. The various subjects embraced under general mineralogy are treated concisely in the first seventy pages and the remainder of the book is given to the description of species.

19. *Determination des Feldspaths dans les plaques minces;* par A. MICHEL-LÉVY. 2d fasc., pp. 71–108, Pls. ix–xxi, (Baudry et Cie.) Paris, 1896.—The first portion of this work which has been noticed in this Journal (vol. xlviii, p. 173, 1894) has already proved of great service to mineralogists and petrographers, and this addition will also be found extremely useful. A new additional method of determination for the plagioclase series is introduced, depending on the equal illumination (*éclairement commun*) of zonal bands. To it is added a résumé of the optical properties of microcline accompanied by a diagram. L. V. P.

20. *Allgemeine Krystallbeschreibung auf Grund einer vereinfachten Methode des Krystallzeichnens* bearbeitet und mit einer Anleitung zur Anfertigung der Krystallnetze und Krystallmonelle herausgegeben von Dr. AUG. NIES. Mit 182 Originalzeichdungen im Texte. 8vo. 176 pp. Stuttgart, 1895. (E. Schweizerbart'sche Verlagsbuchhandlung—E. Koch.)—The aim of the author in this volume is to present the elements of descriptive crystallography in simple form, and as developed by means of a new method of drawing crystalline forms which, as he states, he has used in his instruction with much success for a number of years. This method is based upon the determination of the angular points of the form, projected by means of the methods of analytical geometry, these being plotted upon sheets of paper ruled in squares of 4^{mm} on the side. The simple mathematical relations needed are explained and instructions given for the application of the method described. The symbols of Naumann are employed throughout, only modified to allow of the designation of each individual face. Numerous figures drawn by the author's method show its practical application.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *On the Diurnal Periodicity of Earthquakes;* by CHARLES DAVISON, M.A., F.G.S. (Abstract received from the author.)—Reference is made to the previous work of De Montessus and Ōmori, the former endeavoring to show that the diurnal periodicity of earthquakes is apparent rather than real, and the latter pointing out that a marked diurnal periodicity characterizes the after-shocks of great earthquakes in Japan. The results of twenty-six registers obtained by means of continuously recording instruments in Japan, the Philippine Islands, and Italy are subjected to harmonic analysis with the following conclusions:—

(1) The reality of the diurnal variation of earthquake-frequency seems to be proved by the approximate agreement in epoch (mean local time) of the first four components (24, 12, 8, and 6 hours) for the whole year at Tokio and Manila, and for the winter and summer halves of the year at Tokio.

(2) In ordinary earthquakes, there is in nearly every case a marked diurnal period, the maximum generally occurring between 10 A. M. and noon. The semi-diurnal period, though less promi-

nent, is also clearly marked, the maximum occurring as a rule between 9 A. M. and noon and between 9 P. M. and midnight. Other minor harmonic components are also occasionally important, the first maximum of the eight-hour component probably occurring about 6.30 A. M., and that of the six-hour component about 3 or 4 A. M.; but for these two epochs the results are not always concordant.

(3) Though the materials are insufficient for any general conclusion, the weaker shocks seem to be subject to a more marked diurnal periodicity.

(4) In the case of after-shocks of great earthquakes, the diurnal periodicity is as a rule strongly pronounced. The maximum of the diurnal period occurs within a few hours after midnight, but the epochs of the other components are subject to wide variation, possibly on account of the short intervals over which the records extend. A special feature of after-shocks is the prominence of the eight-hour and four-hour components.

The epochs of the first four components representing the diurnal variation of seismic frequency are compared in several cases with those for barometric pressure and wind velocity. While the variation of the former cannot be attributed exclusively to either of the latter phenomena, it seems not improbable that the diurnal periodicity of ordinary earthquakes may be due chiefly to that of wind velocity, and the diurnal periodicity of after-shocks chiefly to that of barometric pressure.—*Proc. Roy. Soc.*, London, vol. lx.

2. *Transactions of the American Microscopical Society;* edited by the Secretary. Eighteenth Annual Meeting held at Cornell University, Ithaca, N. Y., August 21, 22, and 23, 1895. Volume xvii, 376 pp., Buffalo, 1896 (The Wenborne–Sumner Co.). —This volume gives a full account of the Eighteenth Annual Meeting of the American Microscopical Society with the papers then read. Among these may be noted the following, all of which are illustrated by plates: Some modifications of stems and roots for purposes of respiration, by H. Schrenk; The lateral line system of sense organs in some American Amphibia and comparison with Dipnoans, and On the Spermatheca and methods of fertilization in some American newts and salamanders, by Dr. B. F. Kingsbury; Comparative Morphology of the brain of the soft-shelled Turtle and the English Sparrow, by Susanna P. Gage. The next meeting of the Society will be held at Pittsburg, Pa., August 18 and 20, 1896.

3. *Handbook of Arctic Discoveries*, by A. W. GREELY, 257 pp., 12mo. Boston, 1895 (Roberts Brothers, Columbian Knowledge Series, No. 3).—The interest and value of this little volume are quite out of proportion to its size. It deals with a subject which has not only the highest interest from the scientific side, but which perhaps more than any other tends to excite the imagination of the general public. Notwithstanding its brevity it gives a well-digested and very readable account of Arctic explorations from the earliest times. Its interest is increased in no

small degree from the fact that it has been prepared by an author who has himself a thorough acquaintance with the Arctic and whose own exploits in this field will never cease to excite admiration.

4. *James Clerk Maxwell and Modern Physics;* by R. T. GLAZEBROOK, F.R.S., 224 pp. 12mo. New York, 1896 (Macmillan & Co.—The Century Science Series).—Modern physics owes to Maxwell perhaps more than to any other of recent physicists, for his keen insight into the scientific problems in which he was interested gave a rare value and originality to all that he wrote. His Treatise on Electricity and Magnetism has been before the public for many years, but no one would venture to say that this mine has been exhausted. The present volume is written by a physicist well fitted to deal with a subject of more than usual difficulty and no one interested in the recent progress in physics, or in the personality of those to whom this progress is due, can fail to be profited by its perusal.

5. *North American Birds*, by H. NEHRLING, Part XIII, pp. 193–240, Milwaukee, Wis. (Geo. Brumder).—The thirteenth part of this interesting and handsomely illustrated work has appeared recently.

6. *Ostwald's Klassiker der exacten Wissenschaften*, (Wm. Engelmann, Leipzig).—The latest additions to Ostwald's valuable series of classic scientific memoirs are the following :

No. 67. Entwurf einer Theorie der Abel'schen Transcendenten Erster Ordnung von Dr. A. Göpel (1847).

No. 68. Das natürliche System der chemischen Elemente. Abhandlungen von Lothar Meyer (1864–1869) und D. Mendelejeff (1869-1871).

No. 69. Ueber Faraday's Kraftlinien, von James Clerk Maxwell (1855-1856).

No. 70. Magnetische Polarization der Metalle und Erze durch Temperaturdifferenz, von Th. J. Seebeck (1822-1823).

No. 71. Untersuchungen über die Reihe $1+\frac{m}{1}x+\frac{m\,.\,(m-1)}{1\,.\,2}\,.\,x^2+\,\ldots$ von N. H. Abel (1826).

Nr. 72. Chemische Analyse durch Spectralbeobachtungen, von G. KIRCHHOFF und R. BUNSEN. (1860.) 74 pages.

Nr. 73. Zwei Abhandlungen über Sphärische Trigonometrie, von LEONHARD EULER. (1753 und 1779.) 65 pages.

Nr. 74. Untersuchungen über die Gesetz der Verwandschaft, von CLAUDE LOUIS BERTHOLLET. (1801.) 113 pages.

Nr. 75. Abhandlung über die Herleitung aller Krystallographischer Systeme mit ihren Unterabtheilungen aus einem einzigen Prinzipe, von AXEL GADOLIN. (1867.) 92 pages.

The Origin and History of Contract in Roman Law down to the end of the Republican Period. (Being the Yorke Prize Essay for 1893.) By W. H. BUCKLER. London: 1895. 228 pages (C. J. Clay & Sons).

Elements of Botany; by J. Y. BERGEN. 57 pp. 12mo. Boston and London, 1896 (Ginn & Company).

Las Rocas Eruptivas del Suroeste de la cuenca de Mexico, par EZEQUIEL ORDOÑEZ. (Boletin d. Inst. Geol. d. México, Num. 2), pp. 1–46. Mexico, 1895.